NURSE ACADEMY

FLUIDS AND ELECTROLYTES

A QUICK AND EASY COMPREHENSIVE BOOK TO UNDERSTAND THE ACID-BASE BALANCE OF THE HUMAN BODY. CLINICAL ASSESSMENT AND MANAGEMENT

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Introduction

Thank you for downloading this book. In this book, we will look at the various electrolytes in the body and find out how they are regulated. We will look at what happens when the different electrolytes are out of balance and will study the purposes of the different electrolytes.

Understanding Body Fluids and Electrolytes

Some minerals, most commonly the macro minerals (minerals the body needs in relatively large amounts), are very important to the body as electrolytes. Electrolytes, therefore, are minerals that carry an electric charge when they are dissolved in a liquid such as blood.

The basic electrolytes found in the body include sodium, potassium, chloride, and bicarbonate. These help in regulating nerve and muscle function and maintain acid-base balance and water balance in the body.

If the electrolyte concentration is high, fluid moves into that compartment through ***osmosis.*** Likewise, if the electrolyte concentration is low, fluid moves out of that compartment.

So, to properly adjust fluid levels, the body actively moves electrolytes in or out of cells to achieve this. Therefore, having electrolytes in the correct concentrations (balance) is very important in maintaining fluid balance among various compartments of the body.

The renal system of the body through the kidneys participates a lot in maintaining concentrations in their optimum levels of electrolytes by filtering electrolytes and water from the blood, returning some to the blood, and excreting any excess into the urine.

If the balance of electrolytes is disturbed, several disorders can develop. Electrolyte, therefore, results from the following:

- Dehydration or overhydration.
- Taking certain drugs for imbalance can example, drugs cisplatin, furosemide, amphotericin B, and hydrocortisone, among others.
- Having certain heart, kidney, or liver disorders.
- Being on intravenous fluids or feedings in inappropriate amounts.

Body Fluids

Total body water is about 40 lts. Most of the body’s water is in the ***intracellular compartment,*** fluid that bathes the cells (25 L of 40 L), and the remaining is in the ***extracellular compartment*** (15 L of 40 L).

In the extracellular fluid, there are two types of fluid; the ***interstitial fluid,*** which accounts for 12 lts. and the ***plasma volume*** (the fluid portion of blood) accounts for 3 lts.

Other extracellular fluid consists of lymph, CSF, eye humor, synovial fluid, serous fluid, and GIT secretions.

Infants have low body fat, low bone mass, and they are 73% or more water. Healthy males are about 60% water, and healthy female is around 50% water. The difference comes in due to higher body fat, smaller amount of skeletal muscle in females.

Total water content in the body decline throughout life. In old age, only about 45% of body weight is water. The following summary shows various body fluid compartments compositions:

- Total body water (40 lts.)
- Intracellular fluid (25 lts. (25% of body weight)
- Extracellular fluid (15 lts. (20% of body weight)
- Interstitial fluid 12 lts. (80% of ECF)
- Plasma (3 lts. (20% of ECF)

Composition of Body Fluids

Water is the universal solvent in the body of organisms. Solutes are therefore classified into two groups:

- ***Electrolytes***: These are inorganic salts, all acids and bases, and some proteins in the body. For example, potassium, sodium, etc.
- ***Non -electrolytes***: They include glucose, urea, creatinine, lipids, and urea.

What Are Electrolytes?

A peek into the Chemistry textbooks will tell us that an electrolyte is “an aqueous solution which acts as a medium to conduct electricity." Or "the solution in which electricity is passed and causes ions to move towards their respective electrodes."

Simply stated, electrolytes help conduct an electric current throughout the body.

Fluid and electrolyte balance is a very important part of what the body needs to do in order to stay healthy.

Fluid is a necessary part of every organ and cell, and fluid makes up much of the extracellular milieu, especially in the bloodstream and interstitial fluid (the fluid outside of the cells but not in the bloodstream).

Electrolytes represent the mineral content of the bodily fluid. The minerals are in their ionized form, meaning they are represented as mineral ions with an electric charge that makes the mineral part of a salt, acid, or base within the body.

For example, sodium and chloride are charged as being positive and negative, respectively. They, therefore, have a great affinity for one another. When sodium levels are high, for example, there will be a corresponding elevation in chloride. Potassium and chloride are commonly found together within the cells but not so much outside of the cells.

To make matters interesting, there is a great difference in the concentration of electrolytes when comparing the content of electrolytes in the cells as opposed to out of the cells. This difference is maintained by tiny pumps, which constantly and instantaneously react to changes in electrolytes within the cells, pumping in potassium and pumping out sodium and their corresponding negatively charged ion. Water balance within the cells is balanced purely by passive movement across the cell membrane.

Besides their function as salts in the body, electrolytes can also make up parts of the acids and bases within the cells and body tissues.

Acid-base neutrality with a pH of about 7.4 is necessary within the body for the proper environment for cellular and extracellular enzymatic processes so that, if the electrolytes are not at their proper concentration and the pH level fails to remain at optimal, the enzymatic activity of various body enzymes can be severely compromised.

Humans, as well as nearly all animal forms, require that even subtle changes in electrolytes must be adjusted so as to keep the proper amounts of the various electrolyte salts within the body. These adjustments are particularly important for proper muscle function and nerve function.

Muscle function and the nerves of the body depend on a specific body pH in order to function. This pH balance is maintained by the salts (electrolyte salts) of the body. If the pH is too low or too high, these bodily functions don't work properly.

For example, consider muscle contractions. For muscles to contract properly, there must be sufficient amounts of calcium ions, potassium ions, and sodium ions.

If these are not in their proper concentration, one can develop muscle weakness or an excess of muscle contraction (tetany). Situations of electrolyte imbalance can be life-threatening. For this reason, electrolyte imbalances are treated using oral or IV methods.

If a person suffers from an electrolyte imbalance, it can mean that some part of the body's regulating mechanism in maintaining the proper levels of electrolytes is not working properly. Hormones that regulate electrolyte balance include antidiuretic hormone, parathyroid hormone, and aldosterone. In this book, we will discuss these regulating hormones and what happens when they are insufficient or found in excess quantities.

For electrolytes to be in the proper concentrations in the body, one must neither be over hydrated nor dehydrated. The kidneys are mostly responsible for keeping the body hydrated to a proper degree. In situations of dehydration or overhydration, the concentrations of the various salts are affected, and there can be serious neurological complications, muscle disturbances, and heart problems. These situations often call for immediate medical emergency treatment in order to restore the proper electrolyte and water balance.

Measuring Electrolyte Levels

For all of the available electrolytes, there are blood tests available to check their level. In fact, part of a basic chemistry profile is the measurements of the various electrolytes of the body. This is done using ion-selective electrode technology that can tell the difference between the different electrically charged ions. Along with the electrolyte content checked on a blood test, kidney function is also assessed as the kidneys are partly responsible for what the electrolyte concentration is.

Normally, just the sodium and potassium levels are evaluated with the chloride level calculated from the sodium level provided by the machine. An exception to this is when doing arterial blood gases, in which the chloride level is measured directly along with the blood gas interpretation.

A urine test can also be assessed to see if the electrolytes are properly balanced. When a specific gravity test is done on a urine sample, it can tell if there is an electrolyte imbalance occurring.

What Do Electrolytes Do in the Body

Electrolytes are the electrically charged particles (called ions) in our bodily fluids that are used in the creation of the electrical energy that our body needs for its basic functions.

A layman's super-simplified definition of electrolytes would be—the stuff in your fluids that provides electrical energy.

Electrolytes Fuel Cells

Cells are the building blocks of your body.

Your body's brilliant web of tissues and cells depends on the proper balance of electrolytes, successfully carrying electrical signals, so they can get their specific jobs done.

It is the body fluids such as blood, plasma, the fluid around the cell, and the fluid found inside the cell (called extracellular fluid or interstitial fluid, and intracellular fluid) that provide transportation to these electrolytes.

Knowing all this, we can understand how the fluid part is just as important as the electrolyte part:

- The electrolytes need the fluid, and the body needs the electrolytes.
- An imbalance in either can wreak havoc on your health and energy.
- Electrolytes really are energy and life to the human body.
- It is also very important that electrolytes stay in those specific concentrations within your body.
- A specific ratio is needed between the fluid level in your body and the electrolytes.
- A fluctuation out of that normal range is called an “electrolyte imbalance.”

An electrolyte imbalance isn't something to be taken lightly. Because electrolytes are vitally important to so many body functions, even a small imbalance—either higher or lower than normal-could contribute to a significant or even life-threatening medical condition.

Electrolytes, just like everything else that makes our beautiful body tick-get used up and need to be replenished.

Ideally, your body receives its electrolytes from your diet, more specifically from mineral-rich fruits, veggies, seeds, and grain.

The concern arises when your body loses or uses the electrolytes faster than they are coming in, and its intelligent balance of life (called homeostasis) goes array.

Common Causes to Electrolyte Imbalances

- Kidney disease
- Thyroid disorders
- Vomiting for prolonged periods
- Diarrhea
- Severe dehydration
- Sweating
- Extended periods of physical exertion
- Over-hydration (yes, there is a thing as too much water)
- Acid-base (pH) imbalance in the body
- Congestive heart issues
- Cancer treatment
- Surgery
- Some drugs, such as diuretics or ACE inhibitors
- Eating disorders such as Anorexia and Bulimia
- Malnutrition
- Sever body trauma
- Alcoholism or drug use

The Electrolyte Main Players

Although there are more minerals that can carry an electric charge in the body (aka electrolytes), these are the 7 heavy hitters and some of what they do.

I'm sure their names are going to look familiar:

1. Sodium (Na+)
2. Chloride (Cl-)
3. Potassium (K+)
4. Magnesium (Mg++)
5. Calcium (Ca++)
6. Phosphate (HPO4–)
7. Bicarbonate (HCO3-)

How the Body Regulates pH

The ideal pH level of the body is 7.4, and a normal pH level ranges anywhere between 7.35 and 7.45. The body maintains its pH level by keeping the ratio of bicarbonate hydrogen ions

(HCO3–) to carbonic acid (H2CO3) at a 20:1 ratio. This relationship, however, constantly changes and is only recovered thanks to our lungs and kidneys.

Acidosis occurs when the body's pH falls below 7.40. It is considered to be an *uncompensated acidosis* when the pH falls below 7.35. Alkalosis occurs when the body's pH rises above 7.40. it is considered to be an *uncompensated alkalosis* where the pH is above 7.45.

The body has two natural buffer systems that help to regulate the pH, thereby preventing acidosis and alkalosis from occurring:

- *The lungs:* Retain and excrete carbonic acid in the form of carbon dioxide (CO2).
- *The kidneys:* Assist in regulating pH by excreting or retaining sodium bicarbonate (NaHCO3). They also do this by excreting both acidic and alkaline urine. The kidneys also help secret free H+ ions and by reabsorbing NaHCO3.

Acidosis and alkalosis are both abnormal conditions that are typically caused by a condition or disease.

In order to determine whether a client is in respiratory or metabolic acidosis or alkalosis, it is important to understand the normal blood gas values.

The normal PaCo2 blood gas value is 35−45 mm Hg. An abnormal PaCO2 with normal HCO3 indicates that the condition is *respiratory:*

- PaCO2 greater than 45 is indicative of respiratory acidosis
- PaCO2 below 35 is indicative of respiratory alkalosis

The normal HCO3 blood gas value is 22−26 mEq/L. An abnormal HCO3 with normal PaCO2 indicates that the condition is *metabolic:*

- HCO3 below 22 is indicative of metabolic acidosis
- HCO3 greater than 36 is indicative of metabolic alkalosis

It is important to remember these values for the exam. In the next section, we will discuss how these disorders can occur, the associated symptoms, and how a nurse should care for a client with acidosis or alkalosis.

Chapter 1. Balancing Basics

Balancing Water and Electrolytes in the Body

Our body contains more water than you might expect. It is estimated that more than half of all our weight is strictly in the form of water. Women have a lesser water percentage than men (55% when compared to men at 60%). This is because women have more fat in proportion to other body tissues and because fat cells have a lesser percentage of water in them when compared to other types of cells. Children contain more water by percentage at 70% when compared to adults; older adults have a lower percentage of body water than younger adults. On average, a 150 pound male has about 10 gallons of water in his system, of which 2/3 to 3/4 are in the cells, with the rest as part of the interstitial fluid (at 7 gallons) or as blood (about one gallon). Water can shift rapidly from one fluid space to another through the process of osmosis.

Because our kidneys constantly excrete water, we must make up for the losses by drinking water in any form. Without proper water intake, the kidneys eventually shut down, we get dehydrated, and we run the risk of electrolyte disturbances that can cause further disarray when it comes to bodily functions.

It is better to drink too much water than to drink too little; our kidneys get rid of excess water quite readily as long as they are functioning properly.

Gains and Losses of Water

Water is taken in primarily by drinking water-containing foods. The water is absorbed from the gastrointestinal tract into the bloodstream, where it is distributed where it is needed. Much smaller amounts of water are byproducts of cellular metabolism. This amount of water usually remains in the cell in which the metabolism occurred.

Water is lost by the body in several different ways. The primary way we lose water is through the kidneys, which can filter and excrete many gallons of water in the urine each day, if necessary. Water is also lost through skin evaporation—about 1.5 pints per day. More is lost if we are sweating in the heat. Water is also more humidified going out of the lungs when compared to water taken in through the air, so we lose a small amount of water just in the act of breathing.

Some water is lost through the stool, but this varies from person to person.

Severe diarrhea can actually result in dehydration as there is

not a normal mechanism to conserve water in the GI tract when an inflammatory process in the gut results in water rushing through the GI tract from the blood and into the stool. Vomiting excessively can lead to dehydration as well as diarrhea. Dehydration requires oral or IV water replacement, preferably before the dehydration becomes too severe. If the dehydration comes in the form of excessive vomiting, fluids must be given by IV so that they stay in the system.

Electrolytes in the Body Water

The water in the body has many different substances in it, particularly electrolytes in the form of sodium salts. There is a strong connection between the balance of water and the balance of electrolytes in the body. Because the electrolyte balance is a greater priority, the body will adjust itself as much as is possible to keep the electrolyte concentration the same. If, for example, you have an elevation in sodium in the bloodstream, you will experience a desire to drink water in order to dilute out the over-saturated bloodstream. The kidneys will also hold onto water so the sodium concentration can be improved.

There is a brain hormone located in the pituitary gland known as vasopressin or antidiuretic hormone (ADH) that is secreted

whenever the body senses it is dehydrated. The elevated ADH level will trigger the kidneys to hold onto more water. As you become more hydrated, ADH levels fall back down. On the other hand, if the sodium content of the blood is too low, the kidneys are signaled by low levels of ADH to excrete additional water so that the sodium electrolyte balance is restored.

Fluid Volume Excess

Fluid volume excess is also known as hypervolemia. This can occur when the volume of fluid intake is far in excess of the fluid that can be excreted from the body. The body has several mechanisms for coping with increased fluid intake. It is only when these mechanisms become saturated, which happens in advanced disease conditions, that the clinical manifestation of hypervolemia sets in.

Causes of Hypervolemia

There are two main reasons for which fluid content in the body would increase:

- *Increased intake*: Excessive intake rarely leads to hypervolemia as the body automatically tends to excrete excess oral intake. However, this can occur iatrogenically if excess fluid is given intravenously during fluid resuscitation therapy.
- *Decreased output*: If the body fails to clear fluids at the same rate as intake, water retention can occur, leading to hypervolemia. This can occur in two ways:

1. **Failure of excretion of total fluid:**

This can occur if the kidney fails to function and urine does not form. The kidney retains water, which will later on the move to the interstitial space. This is also seen in mineralocorticoid excess, which causes sodium and water retention by the kidneys.

2. **Failure of fluid movement between compartments:**

If any disease process disturbs this movement, fluids may accumulate in the interstitial spaces. This can happen in the following situations:

- **Decreased arteriolar resistance:** This may be seen if a patient is taking vasodilator drugs or there is insufficiency of the sympathetic nervous system. This increases the hydrostatic pressure to drive blood into the interstitial spaces.
- **Increased venous pressure:** This may be seen in cardiac failure, venous obstruction, or in cases where the valvular mechanism of the veins fails, thereby

causing backing up of blood from the veins to the capillaries. The backed-up blood volume increases the hydrostatic pressure of the capillaries and causes fluid to shift into the interstitial space.

- **Decreased plasma osmotic pressure:** This can occur if the solutes of the plasma decrease. Plasma protein loss can occur in nephritic syndrome and burn injuries. The production of plasma proteins may be halted in conditions like liver cirrhosis and severe malnutrition. When the plasma osmotic pressure is low, the capillaries fail to reabsorb the interstitial fluid. This can cause fluid accumulation in the interstitial space.
- **Increased capillary permeability:** Inflammatory reactions, immune reactions, ischemia, and infections can cause capillaries to become "leaky," which causes fluid to escape from them to the interstitial space.
- **Lymphatic blockage:** A small percentage of interstitial fluid is drained by lymphatics, and if these channels are blocked, fluid can accumulate over time. This can occur in infectious conditions such as filariasis, which causes lymph node swelling. It can also occur when lymph nodes are surgically removed after treatment for malignant disease.

The interstitial space has various coping mechanisms to deal with the excess fluid overload. One mechanism is by increasing the hydrostatic pressure of the interstitium so that it resists the capillary pressure and does not receive fluid. The second mechanism is by increasing the lymphatic outflow.

Lastly, in later stages, proteins get washed out from interstitial spaces, reducing their osmotic pressure.

Fluid accumulation occurs only after these coping mechanisms reach their limits. Therefore, the clinical manifestation of hypervolemia generally is a sign of advanced disease.

Fluid Volume Deficit

A fluid volume deficit can happen if the person loses more fluids from his body than he takes in. Fluid loss can occur from any of the compartments. The fluid loss that occurs exclusively from the intravascular space is referred to as hypovolemia. On the other hand, dehydration is a form of fluid deficit that is spread across all the fluid compartments.

Dehydration

This is a deficit of total body water. There is a loss of fluid from all the body compartments.

Causes

Dehydration can occur in two scenarios—if the total water intake has decreased or if there is excessive total water loss from the body.

Decreased Intake

- **Blunted thirst mechanism—**seen in elderly patients.
- **Lack of available water—**This can occur in extreme situations, such as when a person is lost in the desert or at sea.
- When a patient is asked to be “nil per mouth” before surgery, and adequate fluids are not given intravenously.

Excessive Water Loss

- Vomiting and diarrhea can quickly cause the loss of large volumes of water.
- **Excessive sweating:** can occur with sports, overexertion, and high fevers.
- **Excessive urination:** In uncontrolled diabetics and with drugs such as diuretics.

Classification of Dehydration

Generally, when body fluid is lost, there is variable loss of electrolytes as well, particularly sodium. Depending on the amount of electrolyte that is lost, dehydration can be classified as follows:

TABLE 1. TYPES OF DEHYDRATION

Type of dehydration	Plasma osmolarity	Condition seen
Isonatremic	130–150 mEq/L	Equal loss of sodium and water
Hyponatremic	< 130 mEq/L	Lost fluid has excessive sodium
Hypernatremic	> 150 mEq/L	Lost fluid has minimal sodium

Signs and Symptoms of Dehydration

If you become dehydrated for whatever reason, these are the signs and symptoms you might expect to have:

- *An increase in thirst*
- *Feeling sleepy or tired*
- *Having a dry mouth*
- *Feeling dizzy*
- *Having a low urine output with dark yellow urine*
- *Having no tears when crying*
- *Having a headache*
- *Having extremely dry skin with increased “tenting” of the skin when the skin of the back of the hand is pinched*
- *If you are impaired as to your level of consciousness, you may not feel thirsty, and this can impact your ability to take in enough water; instead, IV hydration may be necessary*

The signs and symptoms depend on the stage of dehydration in which the patient presents:

1. **Mild dehydration: (fluid loss of 30−50 ml/kg)**

- The earliest symptom is a feeling of dryness of the mouth and tongue.
- Headache, tiredness, and loss of appetite.
- Reduced urination (unless the cause is polyuria). This is a sign that can be checked in infants, who will have fewer wet diapers.
- Infants and children will also present with irritability.
- Capillary refill time is 2 seconds.
- Heart rate is normal or increased. Blood pressure and respiratory rate are normal.

2. **Moderate dehydration: (fluid loss of 60−100 ml/kg)**

- Dryness of mouth and mucous membranes increases
- Sunken face and eyes
- Skin is dry and inelastic, turgor is slow
- There will be reduced lacrimation, along with decreased urine output
- Dizziness and lethargy may be present
- Capillary refill time 2−4 seconds
- Heart rate increases, blood pressure drops, and respiratory rate increases

3. **Severe dehydration: (fluid loss of 90−150 ml/kg)**

- The features resemble that of moderate dehydration but are increased in severity
- A patient will be disoriented and confused
- Skin and mucous membranes become parched and cracked. Skin turgor is lost completely, and tenting takes place
- Capillary refill time is more than 4 seconds
- Urinary output is very low; anuria may be present

Consequences of Severe Dehydration

Severe dehydration has additional symptoms than those listed above. A severely dehydrated patient may have:

- A severe lack of urine output of deeply-colored urine
- Rapid heart rate
- A drop in blood pressure when standing (also called orthostatic hypotension)
- Dizziness that is worse upon standing
- Confusion, lethargy, or coma
- Fever
- Low skin elasticity
- Seizures
- Shock

These symptoms require immediate IV hydration so as to save the person from dying of their dehydration:

- **Seizures:** This can occur if the plasma sodium falls.
- **Pontine necrosis and cerebral edema:** This is a consequence of rapid rehydration and not the dehydration process itself. Rapid rehydration causes a rapid rush of water into cells, which may rupture, leading to cerebral edema.

Management of Dehydration

- **Mild dehydration:** This can be corrected by rehydrating the patient with water alone. The patient can take sips of water or ice chips to correct this state.
- **Moderate dehydration:** Usually, this involves a loss of water as well as electrolytes. Oral rehydration solution (ORS) is indicated for the replacement of water as well as lost electrolytes such as sodium and potassium. It is particularly useful in malnourished children from developing countries who are affected by diarrhea. If oral intake is ineffective because of repeated vomiting, a replacement can be done via a nasogastric tube.
- **Severe dehydration:** This requires prompt replacement of fluids but at a slow rate to avoid the complications mentioned above. Intravenous or intraosseous lines must be established. Fluid replacement is preferably done with isotonic solutions such as Ringer’s lactate or 0.9% sodium chloride. If there is symptomatic hyponatremia, replacement is done with a slow infusion of 3% saline solution. Repeated monitoring is essential to adjust the amount of fluid given.

Supportive therapy and treating the cause of dehydration are important steps in management.

Anti-emetics such as Ondansetron have been found effective in severe vomiting. However, routine use of antibiotic therapy and anti-diarrheal agents is not recommended.

Balancing Water in the System

Water is one of the few body molecules that move passively through osmosis to all areas and compartments of the body. This means that if a cell or body tissue is low in the water, the gradient of water is off, and water will naturally flow from one area of the body to the needed area. Because the sodium and other electrolyte content of the bloodstream need to be controlled above all things, there is a natural tendency for blood to passively flow from the cells and interstitial tissue into the bloodstream to maintain normal electrolyte levels.

When Rehydration is Necessary

In situations of the low water content of the body, this usually occurs along with a loss of sodium and potassium, which are excreted in sweat and by the kidneys. If IV supplementation is necessary, it is usually done by hanging a bag of normal saline (which has the proper amount of sodium chloride in the solution and infusing it directly into a peripheral vein. Often potassium is added to the bag of normal saline to make a balanced salt solution for the bloodstream.

Rehydration can also be done orally if the individual can take in fluids. Water containing sugar for fuel and electrolytes such as is found in oral rehydration solutions like PowerAde and Gatorade can help rehydrate the individual quickly and effectively. Electrolytes can also be given in the form of coconut water, nuts, milk, and fruit juices. Many vegetables and fruits contain electrolytes, whether they be taken whole placed in a juicer. Along with the electrolyte-containing foods, you should drink plenty of water in order to add water to the system.

Dehydration appropriate for oral intake can be a result of exercising too much, sweating in the heat, or even drinking too much alcohol, which acts as a diuretic, resulting in a negative water balance. Each of these conditions lends itself to oral rehydration as long as the individual is conscious and has normal swallowing reflexes.

Chapter 2. Fluid and Electrolyte Imbalances

Potassium Imbalance

Potassium is a necessary mineral and is a very important ion in the body. Potassium is of the class of mineral ions, along with sodium, magnesium, calcium, bicarbonate, and chloride; it is essential for life in the human body as well as other animals.

Potassium plays a role in the function of skeletal and smooth muscle, including that of the heart and digestive system. As an electrolyte, it conducts electricity, crucial to intercellular communication.

About 98% of all potassium is found within the cells. A proper balance of potassium in the cells and sodium outside of the cells is made possible by pumps within the cellular membranes that exchange sodium and potassium, keeping more potassium in the cells.

High potassium is known as hyperkalemia, while low potassium is called hypokalemia. A simple blood test can determine the level of potassium in the blood plasma.

Rarely is the potassium checked alone because of more information about the electrolyte content of the blood by testing potassium along with sodium, chloride, and CO**2** levels together.

Hyperkalemia: High Potassium

Causes

- Addison’s disease
- Excessive use of salt substitutes
- Potassium-sparing diuretics
- Renal failure

Symptoms

- Cramps
- Diarrhea
- EKG changes—peaked T waves, wide QRS complexes, or prolonged P-R intervals
- Muscle twitching
- Muscle weakness
- Paresthesia
- Slow pulse rate

Treatment

- Administer calcium gluconate to protect the heart and decrease arrhythmias

- Administer sodium carbonate to counteract acidosis
- Dialysis, particularly if renal failure is present
- Give glucose and insulin to promote movement of potassium from the extracellular space back into the cells
- Monitor digitalis levels
- Monitor intake and output
- Monitor lab values
- Monitor serum potassium and EKG closely

Hypokalemia: Low Potassium

Causes

- Medications such as digoxin, diuretics, and steroids

Symptoms

- Confusion
- The decreased specific gravity of the urine
- EKG changes—inverted T waves, depressed S-T segment
- Lethargy
- Nausea
- Vomiting
- Weak pulse

Treatment

- Change diet by increasing intake of foods high in potassium such as bananas, baked potatoes with the peel, dried fruit, and melons
- Change prescription to potassium-sparing diuretics
- Check magnesium, chloride, and protein levels when replacing potassium
- IV KCI on an IV pump or IV controller
- Monitor input and output
- Give potassium supplements. Before administering potassium, however, the nurse should assess the client's renal function
- Administer oral liquid potassium with juice, such as orange or tomato juice, to facilitate absorption of potassium
- If administering potassium IV, the nurse should dilute the potassium (as it can otherwise cause discomfort by burning the vein) and must always infuse using a controller because hyperkalemia can result in arrhythmias and death
- Potassium regulates protein synthesis, glycolysis, and glycogen synthesis. If cells become damaged, potassium leaves the cell, which can depend on renal function, result in hyperkalemia or hypokalemia

Sodium Imbalance

Sodium is a mineral salt found in high concentrations in the bloodstream and the interstitial fluid. It is used to keep water in these areas through osmosis and is important in the functioning of the muscles and nerves of the body.

About 85% of all body sodium is found in the lymph fluid and blood. Lesser concentrations of sodium are found within the cells. The levels of sodium in the bloodstream are tightly controlled by aldosterone, a hormone secreted by the adrenal glands. When the sodium level gets low, aldosterone sends a signal to the kidneys that tell it to conserve sodium, so it isn't lost in the urine. Another source of sodium loss is sweating; however, this is not controlled and is not a large amount of loss when compared to the kidneys.

Sodium in the bloodstream is often paired with chloride to make the common salt, sodium chloride; however, it can be paired with any positively charged molecule, including bicarbonate. Because sodium levels need to be tightly regulated, routine blood tests often contain a test for the amount of sodium and chloride in the blood.

A simple, non-fasting blood test can be done in order to determine the level of sodium in the bloodstream. The normal sodium level is about 135−145 mEq/ l, although the actual normal range can vary from testing instrument to testing instrument. When getting your sodium level, check the reference range listed along with your value.

Sodium maintains urine concentration, extracellular volume, and acid-base balance. Along with potassium, it also promotes impulse transmission in nerves and muscle fibers. Diet is a major source of sodium. The minimum sodium requirement for an adult is 2 grams a day, although many consume far more sodium. Too much sodium results in hypernatremia. Too little sodium, on the contrary, results in hyponatremia

Hypernatremia: High Sodium

Causes

- Corticosteroids
- Cushing's disease
- Excessive sodium intake
- Fever
- Renal failure

Symptoms

- Agitation
- Confusion
- Decreased myocardial control
- Dry and flaky skin
- Reduced cardiac output

Treatment

- Administer diuretics
- Administer treatment for fever
- Correct water balance
- Decrease sodium content in the diet
- Dialysis
- Monitor intake and output

Hyponatremia: Low Sodium

Causes

- Congestive heart failure
- Diuretics
- Hyperglycemia
- Renal disease
- Wound drainage

Symptoms

- Anorexia
- Decreased sensorium
- Decreased special gravity of urine
- Dry skin
- Headache
- Lethargy
- Mucous membranes
- Muscle weakness
- Oliguria
- Polyuria
- Rapid pulse

Treatment

- Check complete blood count
- Check urine-specific gravity
- Monitor intake and output
- Replace sodium either by adding more to the diet or by IV therapy administration

Chloride Imbalance

Chloride assists in the maintenance of acid-base balances and osmotic pressure. It also promotes the formation of hydrochloric acid. Chloride is regulated by the gastrointestinal system and the kidneys, and chloride intake comes mostly from the diet, in particular foods of high salt content. A higher than normal chloride level results in hyperchloremia, whereas chloride levels that are below the normal value lead to hypochloremia.

Chloride is the main negative ion in the body, both in the cells and out of the cells. The rise and fall of chloride closely mimic the rise and fall of sodium, as they often are found together in an ionic bond within the body tissues. Chloride, in fact, makes up about 70% of the normal body's negative ions. Chloride makes up about 0.15% of the human total body weight or about 115 grams of chloride. Every day, we take in close to 900 milligrams of chloride per day.

Chloride is one of the major electrolyte ions in the body, found in all areas of the body, paired with either sodium (outside of the cells) or potassium (within the cells).

Chloride is responsible, along with the positive ions Na+ and K+, for the electrical messaging between cells, primarily the muscle cells and nerve cells. It is rare to have a chloride deficiency in the body and, when it is low, it usually goes along with a deficiency of sodium as well. Low chloride levels can lead to alkalization of the bloodstream, in which the pH rises above 7.4. You can get hypochloremia in much the same way as losses of sodium are incurred—mainly through serious burn injuries, diseases of water overload, and starvation, with wasting of the body tissues. Infants can develop hypochloremia if they drink formula that does not contain enough chloride. This can cause the infant to fail to thrive, have weakness, and exhibit anorexia. It is possible to have high chloride levels in the body, especially when one consumes large amounts of either sodium chloride (table salt) or potassium chloride (salt substitute). Signs and symptoms of an elevated chloride level include high blood pressure and edema (fluid retention). Most people do not develop a very high level of chloride because their kidneys can excrete any excess chloride in the system, balancing the sodium levels at the same time. Common causes of high chloride in the body include:

- Excessive salt intake
- Renal disease
- Dehydration (such as is seen in vomiting and diarrhea)
- Hyperparathyroidism (an overactive parathyroid gland)

Hyperchloremia: High Chloride

Causes

- Increased consumption of salt

Symptoms

- No specific symptoms other than those that can be associated with an excess of sodium

Treatment

- Assess electrolytes

- Monitor intake and output
- Reduce salt intake in the diet

Hypochloremia: Low Chloride

Causes

- Excessive infusion of hypotonic solutions
- Nasogastric suction
- Sodium deficiency
- Sodium loss through the renal system
- Vomiting

Symptoms

- No specific symptoms other than those that come with a loss of sodium

Treatment

- Administer sodium and chloride
- Monitor for signs of acidosis

Because chloride is such an essential part of health and living, it is often measured as part of an electrolyte profile, a common blood test performed on the body.

A urine test can measure the amount of chloride leaving the body through kidney filtration.

In order to do this test, all the urine excreted during a 24 hours period of time is collected, and the sodium chloride content of the urine is assessed. The levels of potassium, bicarbonate, sodium, and chloride are usually measured from the bloodstream at the same time to get an idea of the electrolyte milieu of the body's bloodstream. Chloride can be measured in a special test called the skin sweat test, in which a patch is placed on the arm for a period of time, and the electrolytes in the sweat on the patch are measured. This is a test for cystic fibrosis.

Calcium Imbalance

Calcium is the most common form of mineral in the body, with the vast majority of calcium being in the bones and teeth (99%). Calcium is also used for the proper functioning of the nerves, the heart, the muscles, and other body symptoms.

Calcium isn't absorbed, nor is it used well if not for the concomitant presence of phosphorus, magnesium, vitamin K, and vitamin D. While calcium supplements are plentiful, the best source of absorbable calcium is through the food you eat. Calcium intake is especially important among young children who are continually growing bones and teeth, as well as in pregnant women. Calcium supplements are generally reserved for the following groups of people:

- *People who use a lot of caffeine*
- *Heavy alcohol drinkers*

- *Postmenopausal women*
- *Soda drinkers*
- *Those who take corticosteroids*

A person is said to have hypocalcemia if they have a total serum calcium level of less than 8.2 mg/dL or an ionized level lower than 4.4 mg/dL. The physical examination may show some of the signs noted above. Patients who have chronic kidney disease or who lost their parathyroid gland function are all at risk for low calcium concentration in the blood.

Calcium assists with the strength and density of teeth and bones, muscle contractility, and normal clotting. Calcium is regulated by the renal system, the gastrointestinal system, and by Calcitonin; a thyroid hormone. A higher than normal calcium level results in hypercalcemia. Calcium levels that are below the normal value lead to hypocalcemia.

Hypercalcemia: High Calcium

Causes

- Excessive calcium and vitamin D
- Glucocorticoids
- Hyperparathyroidism
- Thiazide diuretics

Symptoms

- Decreased clotting
- Disorientation
- **EKG changes—**shortened Q-T intervals
- Hypertension
- Hypotonic bowel sounds
- Increased urinary output
- Renal calculi
- Tachycardia

Treatment

- Assess for renal calculi
- Check for digitalis intoxication
- Check for metabolic alkalosis
- Decrease intake of vitamin D and calcium
- Stay hydrated

Hypocalcemia-Low Calcium

Causes

- Celiac disease
- Crohn’s disease
- End-stage renal disease
- Immobility
- Lactose intolerance
- Pancreatitis
- Thyroidectomy

Symptoms

- An increased heart rate
- Anxiety
- **Positive Chvostek’s sign—**this is done by tapping the facial nerve and checking for facial twitching
- Dental caries
- Dull skin
- **EKG changes—**prolonged S-T and Q-T intervals
- Fatigue
- Hyperactive deep tendon reflexes
- Osteoporosis
- **Positive Trousseau’s sign—**this is done by applying a blood pressure cuff to the arm and checking for carpopedal spasms
- Psychosis
- Thinning hair

Treatment

- Administer calcium and vitamin D supplements
- Check for metabolic acidosis
- Have tracheostomy available should the client experience laryngeal spasms
- Monitor and evaluate EKG
- Seizure precautions

Phosphorus Imbalance

Phosphorus is essential for proper health; it is used in enzymatic reactions that grow and repair tissues of the body. A total of 85% of the phosphorus in the body is found in your bones and teeth, providing strong bones and teeth.

Certain medications, such as antacids and diuretics, can cause a reduction in serum phosphorus content.

Other conditions can result in low phosphorus content, such as

type 2 diabetes, alcoholism, and starvation. Diseases of the bowel such as celiac disease and Crohn’s disease can be so severe as to limit the amount of phosphorus and other minerals absorbed by the GI tract. In such cases, the phosphorus levels can be too low.

If the phosphorus level is too low, some symptoms can be anxiety, bony pain, lack of appetite, osteoporosis, fatigue, joint stiffness, numbness, irritability, breathing problems, and weight fluctuations. Children with low phosphorus levels do not grow properly because they need phosphorus for healthy bone growth and teeth formation.

Too much phosphorus in the bloodstream happens more commonly than in low phosphorus situations.

High phosphorus can be because of kidney disease, taking too much phosphorus in the diet, or consuming too little calcium, which must balance out with the amount of phosphorus you take in. High phosphorus levels are linked to an increase in cardiovascular disease risk. Too much phosphate in your system can lead to phosphorus toxicity, leading to diarrhea and hardening of the arteries (atherosclerosis).

Too much phosphate can also lead to an interference with the ability of the body to use calcium, zinc, magnesium, and iron.

Some athletes take phosphorus before strenuous activity to prevent muscle stiffness. This should only be done under a doctor’s care so that the phosphorus level doesn’t get too high.

Ideally, there should be a balance between calcium and phosphorus intake in the body. Unfortunately, modern western diets contain a great deal more phosphorus than calcium, and calcium must be leached from bones and teeth in order to match the amount of phosphorus in the bloodstream; the bones can become brittle.

Phosphorus assists in the formation and activation of ATP and the activation of the B complex. It also assists in cell development, bone and teeth development, CHO, fat, and protein metabolism. A higher than normal level of phosphorus results in hyperphosphatemia, and a lower than normal phosphorus level can lead to hypophosphatemia.

Hyperphosphatemia: High Phosphorus

Causes

- Decreased renal function
- Hyperparathyroidism
- Hypocalcemia
- Increased phosphorus intake

Symptoms

- Increased serum phosphorus levels
- Muscle spasm
- Positive Chvostek’s sign
- Positive Trousseau’s sign

Treatment

- Administer aluminum hydroxide or other phosphate-binding medications

- Administer calcium supplements
- Decrease diet intake of food containing phosphorus
- Hemodialysis
- Reduce intake of medications containing phosphorus

Hypophosphatemia: Low Phosphorus

Causes

- Aluminum or magnesium antacids
- Hyperglycemia
- Malnutrition

Symptoms

- Cardiomyopathy
- Decreased deep tendon reflexes
- Irritability
- Shallow respiration

Treatment

- Assess calcium levels
- Change diet to increase phosphorus intake
- Give phospho-soda
- Monitor and evaluate EKG
- Monitor for muscle weakness
- Perform neurological assessment

The phosphorus molecule is found inside the body as the phosphate ion. Phosphates are essential to making ATP, which is the main energy molecule in the body. The phosphorus in ATP is lost during an energy reaction in which ATP (adenosine triphosphate) turns into ADP (adenosine diphosphate), releasing energy to cellular power reactions.

Phosphorus is also a major component of DNA and RNA in the cells. Without phosphorus, we would have no genetic blueprint within the cells. If we don’t get enough phosphorus, protein synthesis is impaired, and the cells of the body suffer.

Phosphorus is a natural buffer that acts to neutralize acids in the body so that the pH is kept at 7.4. The hemoglobin in our bloodstream and many bodily enzymes make use of phosphorus as a cofactor or as a part of the structure of the protein itself.

Magnesium Imbalance

Magnesium helps with DNA synthesis, activation of ATP and B complex, and muscle contraction. It also contributes to vasodilation, activates intracellular enzymes in carbohydrates, and assists with protein synthesis, cardiac and skeletal muscle cells. A magnesium level that is higher than the normal value leads to hypermagnesemia, whereas a lower than normal magnesium level results in hypomagnesemia.

Magnesium is actually a common mineral in the body; it is used frequently as a cofactor in more than 300 cellular reactions within the cells. Magnesium is important in energy production, glycolysis, blood sugar control, protein synthesis, muscle function, blood pressure regulation, and nerve production.

Magnesium is essential for bone health and is an essential cofactor in DNA and RNA synthesis. Magnesium is necessary to run the pumps involved in the transportation of potassium ions and calcium ions into and out of the cells. This is extremely necessary for muscle contraction, the maintenance of heart rhythm, and the conduction of nerve impulses.

At any given point in time, our body contains about 25 grams of magnesium, of which more than 50% is found in bone. The rest, around 40−50%, is found in the soft tissue cells, with only 1% residing in serum. The normal range of magnesium in a blood test of serum reveals an average value of 0.75 to 0.95 mmol/L. Any number lower than 0.75 mmol/L is considered hypomagnesemia, and any number above 0.95% is considered to be hypermagnesemia. The homeostasis of magnesium occurs primarily through proper kidney function, which excretes about 120 mg of magnesium daily. If the magnesium levels are low, the kidneys will hold on to more magnesium to achieve homeostasis.

Because the vast majority of magnesium is sequestered in soft tissue and bone, the absolute amount of magnesium is difficult to determine with just a blood test. One of the best tests in assessing the total body levels of magnesium is to give a dose of magnesium by IV and to assess the level of magnesium in

the urine after that. If the magnesium content of the urine is low despite receiving a bolus of magnesium, it is likely that there are low levels of magnesium in the body.

The recommended dietary allowances or RDAs for magnesium vary with age. For example, in small infants, the RDA for magnesium is only 30 grams per day, while in adults, the RDA is between 310 mg and 420 mg per day. Men require more magnesium than women.

Hypomagnesemia is relatively rare due to the ability of the kidneys to hold onto magnesium in times of low magnesium intake. Chronic alcoholism, on the other hand, represents a state of chronically low magnesium, and this is a situation where supplemental magnesium needs to be considered.

While you can’t really suffer from a high magnesium level when you get magnesium from foods, certain supplements, when taken in excess, can raise magnesium levels above the normal range.

High-dose magnesium from medications or supplements can lead to crampy abdominal pain, nausea, vomiting, and diarrhea. The laxative effects of magnesium salts are believed to be due to the osmotic effect of having so much magnesium salt in the colon.

High magnesium levels also increase gastric motility. Magnesium toxicity can rarely be fatal, especially among the very young and the very old. The risk of hypermagnesemia is highest in those who suffer from renal dysfunction (kidney failure), so that the kidneys fail to get rid of excess magnesium in the diet.

Hypermagnesemia: High Magnesium

Causes

- Increased ingestion of magnesium
- Renal failure

Symptoms

- Bradycardia
- Diminished deep tendon reflexes
- Drowsiness
- Hypotension
- Lethargy
- Respiratory depression

Treatment

- Administer calcium gluconate
- Dialysis
- **Monitor deep tendon reflexes (DTRs)—**the absence of patella reflex indicates toxicity
- Monitor intake and output on an hourly basis
- Monitor level of consciousness (LOC)
- Provide ventilator support

Hypomagnesemia: Low Magnesium

Causes

- Alcoholism
- Celiac disease
- Crohn’s disease
- Diarrhea
- Food containing citrate
- Malnutrition

Symptoms

- An increase in blood pressure
- Confusion
- Dysrhythmias
- Hyperreflexia
- Positive Chovstek’s sign
- Positive Trousseau’s sign

Treatment

- **Administer magnesium—**always check renal function before magnesium administration, and if IV magnesium is given, the nurse should always use a controller
- **Monitor deep tendon reflexes (DTRs)—**the absence of which indicates toxicity to magnesium
- **Monitor magnesium levels on an hourly basis—**decreased respiration indicates toxicity to magnesium

Other Imbalances in Common Medical Conditions

Now that an overview has been provided into fluid and electrolyte imbalances, it would have been noted that the cause of most of these imbalances is similar. Generally, dysfunction of any one of the major organ systems or insult to the body as a

whole would bring about changes in the normal homeostatic mechanisms, leading to fluid, electrolyte, and acid-base disorders. These disorders would occur in combination rather than in isolation. A few of the common medical conditions in which these would present are described below:

Hyperthermia

Hyperthermia, or heat stroke, is a condition where the body heats up because thermoregulation fails. This can occur in the presence of excessive environmental heat, excessive exertion, or a combination of both.

Pathophysiology of Imbalances

- Heat causes the body to lose more fluid, both through sweat and insensible losses. Therefore, the patient develops dehydration.
- As fluid loss occurs, the concentration of electrolytes relatively increases. This can lead to hypernatremia.
- Hypokalemia is seen in early heat stroke due to fluid and electrolyte redistribution. However, in later phases, as muscle damage increases, potassium is released from damaged cells, leading to hyperkalemia.
- Hypocalcemia and hypomagnesemia are observed, secondary to other electrolyte disturbances.
- Lactic acidosis may occur because of poor aerobic metabolism and the accumulation of lactates.

Management

- Immediate cooling of the body is the mainstay of treatment and can halt or reverse the disease process. This is accomplished by ice water immersion or evaporative cooling therapy.

- Infusion of dextrose with sodium bicarbonate can provide fluid resuscitation, drive potassium intracellularly, and counter acidosis.
- Calcium must be used only if cardiac signs develop.

Cardiac Failure

Cardiac failure occurs when the heart muscle is unable to pump sufficient blood to meet the requirements of the entire body. The various neurohumoral adaptive mechanisms that take place in heart failure, as well as the various drugs used, can contribute to electrolyte and acid-base disorders.

Pathophysiology of Imbalances

- **Hyponatremia:** when the cardiac output decreases, the renal blood flow and hence glomerular filtrate also decreases, leading to water retention. Apart from this, there is the activation of the renin-angiotensin mechanism as well as the ADH hormone, which leads to more retained water, thereby diluting the sodium content present.
- **Hypokalemia:** this can occur secondary to renin-angiotensin activation and can also be a consequence of diuretic therapy. Hypokalemia is a strong predictor of mortality rate as, by itself, it can cause cardiac arrhythmias in these patients.
- **Hypomagnesemia:** although this is commonly observed in patients with heart failure, its pathophysiology is less well understood. It is believed to be due to reduced dietary intake, renal losses due to diuretics, and redistribution of other electrolytes.
- **Hypocalcemia and hypophosphatemia:** These do not always occur but may sometimes be seen secondary to other electrolyte disturbances.
- **Acid-base disturbances:** Usually, these patients can present with metabolic alkalosis, sometimes in combination with respiratory alkalosis. This is mainly due to the loss of hydrogen ions in the urine and the driving of hydrogen ions intracellularly. Hypoxia, due to reduced circulating blood, is also a contributing factor.

Management

- Since cardiac failure is a condition with high morbidity, the focus is usually on treating the condition properly. Based on the severity, treatment for heart failure ranges from pharmacological therapy and revascularization procedures to a total heart transplant.
- At every stage of therapy, however, the electrolytes and blood gases must be analyzed periodically so that drug therapy may be modified and any electrolyte imbalances may be corrected.
- It is especially important to keep potassium and magnesium levels within their normal ranges, as these electrolytes play an important role in heart health.

Respiratory Disease

Respiratory failure occurs when the lungs fail to facilitate the exchange of carbon dioxide for oxygen. This leads to a lack of oxygen (hypoxia) and excess carbon dioxide (hypercapnia) in the body.

Pathophysiology of Imbalances

- Since the respiratory mechanism of acid-base homeostasis is suppressed, there is an accumulation of carbon dioxide in the body. This results in respiratory acidosis due to raised PaCO2.
- Impaired lung function can eventually cause pulmonary edema and right heart dysfunction, which in turn affects the renin-angiotensin-aldosterone axis, and stimulates ADH release. The net effect is water retention, leading to hyponatremia.

Management

- The mainstay of therapy is correcting hypoxemia. The standard of treatment is extracorporeal membrane oxygenation, which reverses the hypoxia and thereby the hypercapnia.
- Once these abnormalities are reversed, electrolytes must be monitored and corrected if required.
- Severe acidosis may require assisted mechanical ventilation to remove carbon dioxide from the body.

Gastrointestinal Fluid Losses

There are several instances where fluid may be lost from the gastrointestinal tract. While the gastric fluid is acidic, the bile and pancreatic juice secretions are more alkaline. Thus the electrolyte and acid-base imbalance would depend on the type of fluid that is lost.

Pathophysiology of Imbalances

- Vomiting and diarrhea lead to fluid loss, along with loss of sodium and potassium. This is further exacerbated by inadequate intake. Generally, this manifests as hypokalemia and hypochloremia. Hypochloremia results in alkalosis.
- On the other hand, in conditions like pancreatic fistulae, loss of pancreatic juice can cause losses of bicarbonate, along with sodium and potassium, leading to net acidosis.
- **Milk alkali syndrome:** This is seen in peptic ulcer patients who have ingested large quantities of antacids. This is associated with hypercalcemia and mild alkalosis. Magnesium levels may also be raised.
- Steatorrhoea is a condition where there is impaired fat absorption. This also impairs the absorption of calcium and phosphorous, leading to hypocalcemia and

hypophosphatemia.

Management

- Management depends on the cause of gastric fluid losses. Electrolyte monitoring according to the trends mentioned above is essential. Management must be tailored to meet the abnormality.

Renal Failure

Renal failure invariably causes electrolyte abnormalities across the entire spectrum and can result in complex acid-base disturbances.

Pathophysiology of Imbalances

- Since there is the failure of fluid excretion, there is fluid excess, leading to edema. Although sodium is also retained, excessive fluid retention results in a net dilution and hyponatremia.
- **Hyperkalemia:** failure of secretion of potassium in the renal tubule.
- Kidneys are also responsible for the activation of vitamin D, which in turn influence calcium levels. In renal failure, hypocalcemia and hyperphosphatemia are frequently encountered.
- In renal failure, magnesium fails to get excreted, leading to hypermagnesemia.
- Renal failure also prevents reabsorption of bicarbonate, resulting in metabolic acidosis.

Management

- The cause of renal failure must be determined and managed if possible.
- Diuretic drugs are frequently used to remove excess water and electrolytes. However, this must be done with caution as diuretic therapy itself can lead to electrolyte imbalances. Electrolyte monitoring is done frequently, and drugs must be modified or changed as needed.
- Dialysis, both hemodialysis, and peritoneal dialysis, are the mainstay of treatment and remove excess electrolytes.
- Oral bicarbonate supplementation is helpful in cases of chronic kidney failure. Calcium supplementation can be done orally or intravenously.

Burns

Pathophysiology of Imbalances

- Below the large necrotic area of the burn, inflammatory mediators are released. These cause an increase in vascular permeability, causing plasma to shift out of vessels into the interstitial and intracellular space, causing cell edema. Both sodium and water are shifted intracellularly.

Early Phase

- **Hyponatremia:** due to extracellular sodium depletion
- **Hyperkalemia:** released during cell damage of burned area.
- **Acidosis :** secondary to hyperkalemia

Second Phase

- **Hypernatremia:** mobilization of intracellular sodium, activation of renin-angiotensin pathway
- **Hypocalcemia:** due to potassium losses and intracellular shift
- **Hypomagnesemia and hypophosphatemia:** due to loss of other electrolytes

Management

- First, the hyperkalemia is treated:
- Calcium chloride infusion to counter cardiac effects of hyperkalemia
- Drive potassium intracellularly with insulin and glucose infusion
- Sodium bicarbonate to correct acidosis if needed
- Use of diuretics/dialysis to excrete potassium
- If hypernatremia persists, it is corrected with hypotonic fluids
- **All other electrolytes—**calcium, phosphate, magnesium, must be observed every few hours and corrected if needed.

Chapter 3. Arterial Blood Gas Analysis (ABGs)

Arterial blood gases are usually done under critical conditions when there is an issue regarding the ability of the lungs to exchange oxygen and carbon dioxide. The test also determines the acid-base balance in the system by measuring the pH of the blood. Arterial blood gases are a good way of identifying the severity of respiratory and metabolic disorders.

The two main blood gases are oxygen and carbon dioxide. In some situations, such as carbon monoxide poisoning, carbon monoxide can be found in higher than acceptable levels in the blood. Blood pH is measured by a special machine and is normally between 7.35 and 7.45. pH levels less than 7.35 indicate that the blood is too acidic; pH levels greater than 7.45 indicate that the blood is too basic. The body uses bicarbonate (HCO3-) to adjust the pH of the blood. If the blood pH is too acidic, the kidneys increase the pH by increasing the concentration of the blood bicarbonate levels.

In an arterial blood gas measurement, the partial pressure of oxygen (PaO2) and the partial pressure of carbon dioxide (PaCO2) is measured along with the percentage of oxygen saturation.

The blood pH is determined along with the bicarbonate level. The test measures the ability of the lungs to exchange oxygen for carbon dioxide and whether or not there is a metabolic or respiratory acidosis or alkalosis going on.

The normal values are as such:

- **PaO2:** 75−100 mm Hg
- **PaCO2:** 34−45 mm Hg
- **O2 saturation**: 95−100%
- **Blood pH:** 7.35−7.45
- **Bicarbonate:** 20−29 mEq/L

If the pH is too low, the patient has either respiratory or metabolic acidosis. If the pH is too high, the patient has either respiratory or metabolic alkalosis. Blood gases are done in serious cases of chronic obstructive pulmonary disease (COPD), sepsis, kidney failure, pulmonary edema, Cushing disease, diabetes, or drug overdose. All of these can yield a high bicarbonate level.

If the bicarbonate level is too low, it could indicate an overdose of alcohol, liver disease, aspirin overdose, dehydration, severe malnutrition, diarrhea, hyperventilation, kidney disease, shock, severe burns, and hyperthyroidism.

Blood consists of three different forms of carbon dioxide.

They include bicarbonate HCO3-, dissolved CO2, and carbonic acid (H2CO3). Most of the carbon dioxide is in the form of HCO3− ions. The blood gas level measures all forms of carbon dioxide at the same time. The total carbon dioxide level is normally 23−29 mmol/L in adults and 20−28 mmol/L in children. Elevated levels of total CO2 include pneumonia-causing respiratory acidosis, COPD causing respiratory acidosis, Conn syndrome causing metabolic acidosis, Cushing syndrome causing metabolic acidosis, and alcoholism causing metabolic acidosis. Low levels of total CO2 are found in hyperventilation (respiratory alkalosis), cirrhosis (respiratory alkalosis), pneumonia (respiratory alkalosis), liver failure (respiratory alkalosis), diabetes (metabolic alkalosis), diarrhea (metabolic alkalosis), aspirin overdose (metabolic alkalosis), kidney failure (metabolic alkalosis), heart failure (metabolic alkalosis), antifreeze ingestion (metabolic alkalosis), methanol ingestion (metabolic alkalosis), and chronic starvation causing metabolic alkalosis.

Carbon monoxide binds to the hemoglobin cell, displacing oxygen by creating a complex called carboxyhemoglobin. This decreases the amount of oxygen capable of attaching to hemoglobin which can lead to death. Patients with excessive carbon monoxide poisoning will suffer from dizziness, visual disturbances, headache, confusion, muscle weakness, nausea,

and vomiting. Maintaining normal blood pH requires a variety of organ systems and is dependent on circulatory integrity. It is not unusual, then, that disruption of the acid-base equilibrium will complicate the treatment of a wide variety of diseases and cause damage to many areas of the body. The body has a tremendous capacity to maintain blood pH, but diseases affecting it typically include serious chronic disease or acute critical illness.

Arterial blood gas analysis is the most common procedure conducted by nurses on seriously ill patients in the emergency department, the treatment room, and the intensive care unit. One of the procedure's key aims is determining acid-base status, which is frequently interrupted during serious illness. The body's challenge is that normal metabolism is correlated with the constant development of hydrogen ions (H^+) and carbon dioxide (CO_2), all of which help to decrease pH. The process that overcomes this problem and serves to retain normal blood pH (i.e., retaining acid-based homeostasis) is a dynamic synergy of action involving chemical buffers in red cells (erythrocytes) as they circulate.

Normal cell metabolism depends on maintaining blood pH within very narrow limits (7.35−7.45).

Even comparatively minor excursions beyond this standard pH range can have deleterious effects, including the decreased supply of oxygen to tissues, electrolyte disruptions, and changes in heart muscle contractility; survival is unlikely if blood pH is below 6.8 or above 7.8.

To understand how these five components relate to the overall conservation of blood pH, a brief overview of some basic principles will help.

What is an Acid?

An acid is an agent that activates hydrogen ions (H^+) on dissociation in solution. For instance, hydrochloric acid (HCl) dissociates into hydrogen ions and chloride ions.

$$HCl \longrightarrow H^+ + Cl^-$$

Carbonic acid (H_2CO_3) disintegrates into hydrogen ions and bicarbonate ions.

$$H_2CO_3 \longrightarrow H^+ + HCO_3^-$$

We differentiate between stronger acids such as hydrochloric acid and weak acids such as carbonic acid.

The distinction is that strong acids are more dissociated than weak acids.

As a result, the abundance of hydrogen ions in a strong acid is significantly greater than that of a weak acid.

What is the Base?

The base is a substance that accepts hydrogen ions in the solution.

For example, the base bicarbonate (HCO_3^-) uses hydrogen ions to form carbonic acid:

$HCO_3^- + H^+ \rightarrow H_2CO_3$

Disturbances of Acid-Base Balance

Most of the acid-base disruptions are caused by:

- Disease or injury to organs (kidney, lung, brain), the normal function of which is essential for acid-based homeostasis.
- A condition that induces abnormally increased development of metabolic acids so that homeostatic processes are overloaded.
- Medicinal intervention (e.g. mechanical ventilation, some drugs).
- Arterial blood gases are blood samples used to diagnose and track acid-based disruptions. Three parameters calculated during the blood gas study, arterial blood pH (pH), partial carbon dioxide pressure in arterial blood (pCO_2(a)), and bicarbonate concentration (HCO_3^-), are of critical importance (see Table I for comparison [normal range]).

The results of these three make the classification of acid-base disruptions into one of four etiological categories:

- Respiratory acidosis
- Respiratory alkalosis
- Metabolic acidosis
- Metabolic alkalosis

	Adults	Neonates
pH	7.35−7.45	7.30−7.40
pCO_2 (kPa)	4.7−6.0	3.5−5.4
Bicarbonate (mmol/L)	22−28	15−25

Table I. Approximate reference (normal) ranges.

To understand how pH, pCO_2(a), and bicarbonate effects are used to describe acid-base disturbances in this way, reference must be made to the Henderson-Hasselbalch equation.

$pH = 6.1 + \log ([HCO_3^-] / [H_2CO_3])$ There is, however, a relationship between pCO_2(a) and H_2CO_3, which results in the readjustment of the Henderson-Hasselbalch equation for the three parameters (pH, pCO_2(a) and bicarbonate) measured during the blood gas analysis: $pH = 6.1 + \log ([HCO_3^-] / (pCO_2(a) \times 0.23))$ By extracting all constants from this equation, the relationship between the three calculated parameters can be described more simply: $pH \propto [HCO_3^-] / pCO_2(a)$ This relationship, crucial for understanding all that follows acid-base disturbances, states that arterial blood pH is proportional to bicarbonate concentration ratio to pCO_2(a). It allows the following deductions:

- pH remains normal as long as the ratio $[HCO_3^-]$: pCO_2(a) remains normal.
- pH increases (i.e., alkalosis occurs) as either $[HCO_3^-]$ increases or pCO_2(a) decreases.
- pH reduces (i.e., acidosis occurs) as either $[HCO_3^-]$ decreases or pCO_2(a) increases.
- If relatively the same amount increases both pCO_2(a) and $[HCO_3^-]$, the ratio, and

therefore the pH, is normal.

- If the same amount decreases both *p*CO2(a) and [HCO3–], the ratio and the pH are normal.

Acid-based disturbances mainly affect either *p*CO2(a), in which case they are referred to as respiratory disorders or [HCO3–], in which case they are referred to as non-respiratory or metabolic disorders:

- If the main disruption is elevated *p*CO2(a) (which causes acidosis – see above), the disorder is called respiratory acidosis.
- If the main disturbance is decreased *p*CO2(a) (which induces alkalosis, see above), the disease is called respiratory alkalosis.
- If the main disorder is associated with decreased bicarbonate (which occurs in acidosis, see above), it is termed metabolic acidosis.
- If the main change is associated with elevated bicarbonate (which results in alkalosis—see above), the disorder is termed metabolic alkalosis.

ABG vs. VBG

A VBG, on the other hand, analyses venous blood and can reliably calculate pH and CO2 but cannot provide consistent CO2 results. For this cause, arterial monitoring has become the "gold standard" in patients at risk of rapid decompensation or those with a respiratory element.

ABGs are drawn for several reasons. These may include:

- Uncontrolled diabetes
- Ketoacidosis
- Lung Failure
- Kidney Failure
- Shock
- Trauma
- Asthma
- Hemorrhage
- Drug Overdose
- Metabolic Disease
- Chemical Poisoning
- Chronic Obstructive Pulmonary Disease (COPD)
- To confirm if lung-condition treatments are working (patients on ventilators or oxygen therapy).

Blood Gas Results in Disruptions of Acid-Base Balance

Respiratory compensation for primary metabolic disturbance happens much more quickly than metabolic (renal) compensation for primary respiratory disturbance. In the second example, compensation takes place over days rather than hours.

Metabolic alkalosis is only rarely completely compensated for the factors mentioned above.

Mixed Acid-Base Disturbances

It may be implied from the above discussion that all patients with acid-base disturbance have only one of the four types of acid-base equilibrium, but patients may have more than one disruption in specific cases.

Consider, for example, a patient with chronic lung disease such as emphysema with long-term partly-compensated respiratory acidosis. If this patient already had diabetes and did not take his usual insulin dosage and was then in a state of diabetic ketoacidosis, the blood-gas effects would reflect the cumulative effect of both respiratory acidosis and metabolic acidosis.

Such mixed acid-base disruptions are not infrequent and can be difficult to unravel, based on arterial blood gas findings alone.

Arterial blood gas analysis results can identify acid-base disturbance and provide valuable information as to its cause.

The acronym *"ROME"* is used as a bit of help to remember the correlation between pH and CO_2.
*R*espiratory *O*pposite—In respiratory syndromes, the pH and CO_2 arrows are in opposite directions.
*M*etabolic *E*qual—In metabolic syndromes, the PH and CO_2 arrows are in the same direction.

Acid-Base Disturbances and the Body's Reaction

Primary disturbance	Example	Initial blood pH	Compensatory mechanism	Compensatory change in blood pH
Metabolic acidosis	Increased synthesis of acid due to diabetic ketoacidosis	Too low	Increased breathing rate to eliminate carbon dioxide	Increases back to normal
Respiratory acidosis	Decreased breathability due to serious chronic lung disease	Too low	Increased urinary acid excretion	Increases back toward normal
Metabolic alkalosis	Loss of stomach acid caused by vomiting	Too high	Decreased breathing rate to retain carbon dioxide	Decreases back toward normal
Respiratory alkalosis	Hyperventilation due to anxiety	Too high	Increased excretion of alkali in the urine	Decreases back toward normal

Examples of ABGs

These examples are provided to assist students:

Example 1

You are asked to look at a 63-year-old lady who was admitted with breathing difficulties. Upon admission, the patient looks sleepy and is using 10 lts. of oxygen via a mask. You conduct an ABG that shows the following results:

- **pH:** 7.29 (Normal 7.35−7.45)
- ***p*CO2:** 9.2 kPa (4.7−6.0 kPa) or 68.2 mmHg (35.2−45 mmHg)
- ***p*O2:** 7.0 kPa (11−13 kPa) or 52.5 mmHg (82.5−97.5 mmHg)
- **HCO3–:** 26 (22–26 mEq/L)
- **Base excess:** +1 (-2 to +2)

Interpretation

- The *p*O2 is low, so the patient is in respiratory failure.
- The pH shows an acidosis and assesses the CO2 to see if it contributes to the acidosis (↑CO2)
- In this given case scenario, the *p*CO2 is raised significantly, which is likely to cause acidosis.
- In the context of low *p*O2, a raised *p*CO2 suggests the patient has type 2 respiratory failure.
- The HCO3 is normal, so the metabolic system does not contribute to the acidosis and is not compensating for the respiratory acidosis, suggesting that this is an acute derangement.
- The base excess is within usual limits as there has been no major improvement in the quantity of HCO3–.
- If this respiratory acidosis is chronic, we would expect the kidneys to produce more HCO3– compensation, which would have resulted in an improved BE.
- *Thus, it is* respiratory acidosis.
- Respiratory acidosis was caused by type 2 respiratory dysfunction (failure of ventilation) due to elevated levels of CO2 (hypercapnia).
- Confusion
- Reduced consciousness level
- Asterixis
- Bounding pulse
- Type 2 respiratory failure happens as a result of a ventilation failure.

The probable causes of this include those mentioned below:

• Potential causes of type 2 respiratory failure
• Increased resistance of airways—COPD/asthma

• Reduced respiratory effort—opioid effects (e.g. opiates)/brain stem lesions/extreme obesity
• Decreased lung area available for gas exchange—chronic bronchitis
• Neuromuscular complications—Guillain-Barré syndrome/motor-neuron disease
• Deformity—ankylosing spondylitis/flail chest.

Example 2

A 17-year-old teen complains to A&E of a tense sensation in her chest, shortness of breath, and some tingling in her fingertips and around her lips. She has no relevant prior medical records and is not on any daily medications. The ABG is performed on the patient while breathing room air, and the findings are shown below:

- **pH:** 7.50 (Normal 7.35–7.45)
- ***p*O2:** 14 kPa (11–13 kPa) or 105 mmHg (82.5–97.5 mmHg)
- ***p*CO2:** 3.4 kPa (4.7–6.0 kPa) or 24 mmHg (35.2–45 mmHg)
- **HCO3–:** 22 (22–26 mEq/L)
- **Base excess:** +2 (-2 to +2)

Interpretation

- A *p*O2 of 14 kPa on-air is at the upper limit of normal, so the patient is not hypoxic.
- The pH of 7.49 is greater than average, and thus the patient is alkaline.
- The next step is to determine when the respiratory system leads to alkalosis (e.g. CO2).
- CO2 is poor, associated with alkalosis, but we now realize that the respiratory system responds to alkalosis, likely to be the whole cause.
- The next step is to look at HCO 3-and see if it still leads to alkalosis.
- HCO3-is normal, except in mixed respiratory and metabolic alkalosis, leaving us with isolated respiratory alkalosis.
- The bicarbonate is at the low end of its usual state, but this does not reflect compensation.
- Compensation will require a significantly larger reduction in HCO3–.
- *This, is* respiratory alkalosis.
- Respiratory alkalosis occurs because of increased ventilation, which can be caused by any of the following:

• **Anxiety—**panic attack
• **Pain—**causing raised respiratory rate
• **Hypoxia—**sometimes seen after climbing too high altitude

• Pulmonary embolism
• Pneumothorax
• Iatrogenic (unnecessary mechanical ventilation).

- A previously stable young person who had hyperventilation with peripheral and peri-oral tingling will have a reasonably common history of a panic attack (anxiety).
- As blood plasma becomes more alkaline, the concentration of freely ionized calcium, the biologically active portion of blood calcium, reduces (hypocalcemia).
- Since a portion of both hydrogen ions and calcium is tied to serum albumin, as blood becomes alkaline, bound hydrogen ions dissociate from albumin, release albumin to bind more calcium, and decrease the freely ionized portion of overall serum calcium that contributes to hypocalcemia.
- This hypocalcemia related to alkalosis is responsible for the paresthesia often seen with hyperventilation.

Chapter 4. Causes of Acid-Base Disturbances

Metabolic Acidosis: pH Down, CO2 Down, and HCO3 Down

Metabolic acidosis happens when the pH falls below 7.40. This is triggered either by a loss of bicarbonate hydrogen ions (HCO3–) or a significant gain of carbonic acid (H2CO3).

Common causes of metabolic acidosis include:

- *Anorexia:* Which causes cell starvation.
- *Certain disease states***:** Disease states that lead to excessive metabolism of fats in the absence of usable carbohydrates - can result in a rise of ketoacids.
- *Diabetes mellitus:* A lack of usable insulin can lead to ketoacidosis and hyperglycemia.
- *Diarrhea***:** Loss of HCO3 can lead to dehydration. Dehydration is a common cause of acidosis.
- Excessive ingestion.
- Chronic diarrhea
- Malnutrition
- Starvation
- Renal failure
- Diabetic Ketoacidosis (DKA)
- Trauma
- Shock
- Sepsis
- Salicylate toxicity
- Lactic acidosis.
- *Overuse of diuretics***:** In particular, overuse of non-potassium-sparing diuretics.
- *Sepsis or overwhelming infections:* Sepsis can lead to cell death and, therefore an accumulation of nitrogenous waste.
- *Renal failure***:** Renal failure can lead to the accumulation of waste in the body. —
- *Terminal stages of Addison's disease***:** Adrenal insufficiency results in sodium and water loss which leads to a decrease in blood pressure and hypovolemic shock.

A nurse should also know and recognize the *symptoms of metabolic acidosis,* which include:

- A decrease in PaCO2
- A decrease in pH
- A decreased serum CO2
- Increased ventilation
- Dyspnoea
- Chest pain

Other signs are as follows:

- Palpitations
- Headache, fatigue, and confusion
- Nausea, vomiting, and appetite loss
- An increase in potassium

- Anorexia
- Coma
- Diarrhea
- Drowsiness
- Fruity breath
- Headache
- Hyperventilation
- Increased acid in the urine
- Large volumes of dilute urine (polyuria)
- Lethargy
- Loss of consciousness
- Nausea
- Vomiting
- Stupor
- Abdominal pain
- Confusion
- Kussmaul breathing

Management

- In metabolic acidosis, the body tries to compensate by increasing respiratory rate (Hyperventilation) so that the lungs excrete more CO_2
- Treating metabolic acidosis requires early diagnosis and treatment of the factors that are causing the condition. The following interventions are required to care for a client with metabolic acidosis:
- Monitor the potassium level (K+) of the client and treat accordingly.
- *Hyperkalemia***:** describes the condition where the potassium level in the bloodstream is higher than normal. Symptoms of hyperkalemia include nausea, malaise, diarrhea, muscle irritability, flaccid paralysis, and general weakness.
- *Hypokalemia***:** describes the conditions when there is a deficiency of potassium in the blood. Symptoms of hypokalemia include: vomiting, shortness of breath, diminished reflexes, weak pulse, shallow respirations, and depressed U waves on the ECG.

Note: When administering potassium, remember that it should be given with juice to counter the bitter taste. More importantly, remember to assess the client's renal function before administering potassium. Because the kidney assists in regulating potassium, if potassium is administered and the client has renal disease, this could lead to hyperkalemia which can be life-threatening.

- Monitor for any vital signs as to the quality of pulses, and intake, and output.
- Diabetes should be treated with glucose for hypoglycemia and with insulin for hyperglycemia. *Frequent blood glucose checks should be performed if the client is diabetic.*
- Addison's diseases should be treated with cortisone preparations, fluids for shock, and a high sodium diet.
- Hypovolemia should be treated with blood transfusions, a volume expander, and a

shock.
- Lactic acidosis should be treated with oxygen and NaHCO3.
- Renal failure should be treated with a transplant and diet changes or with dialysis.

The management of metabolic acidosis depends upon two factors—the severity and the cause:

Severe acidosis ($pH < 7.15$), irrespective of the cause, is generally corrected by alkali therapy. This involves the intravenous administration of sodium bicarbonate. 50 to 100 ml ampules of sodium bicarbonate (containing 50−100 mEq NaHCO3) is added to 1 lt. solution of 5% dextrose or 0.25% normal saline and is administered over 30 to 45 minutes. Serum electrolytes must be monitored throughout as alkali therapy can result in hypernatremia or hypokalemia.

The goal of alkali therapy is not to achieve normal pH but to bring the pH to 7.2. Further correction is better achieved by correction of the underlying cause. Continuous alkali therapy can have adverse effects such as volume overload and increased PaCO2, especially in patients with respiratory dysfunction. In lactic acidosis, it can even exacerbate the acidosis by stimulating phosphofructokinase and must therefore be used with caution in these patients.

Cause—Based Treatment

- **Diabetic ketoacidosis:** Insulin therapy.
- **Starvation and alcohol-related acidosis:** Intravenous glucose
- **Salicylate toxicity:** Gastric lavage with saline, followed by activated charcoal
- **Ethylene glycol/ methanol toxicity:** Saline osmotic diuresis, antidote such as fomepizole.

Metabolic Alkalosis: pH Up, CO2 Up, and HCO3 Up

Metabolic alkalosis is caused by an accumulation of HCO3 or a loss of acid that causes the pH to rise above 7.45.

Common causes of metabolic alkalosis include:

- Loss of gastric HCl—vomiting, nasogastric suctioning
- Ingestion of excessive antacids
- Loop diuretics and thiazide diuretics.

Causes of chloride resistant alkalosis:

- Hyperaldosteronism
- Renin increase—tumors
- Normal or increased CO2 levels
- pH levels above 7.45
- NG suctioning
- Prolonged use of Antacids
- Use of diuretics
- **Autosomal recessive syndromes**—Bartter syndrome, Gitelman syndrome
- Hypokalemia, Hypomagnesemia
- Fistulas high in the gastrointestinal tract can lead to a loss of hydrochloric acid
- Ingestion or retention of a base

- Steroid therapy or Cushing’s syndrome (hypersecretion of cortisol) can lead to sodium, hydrogen (H^+) ions, and fluid retention
- Vomiting or nasogastric suction can also lead to loss of hydrochloric acid

It is also important for the nurse and nursing student to know and be able to recognize the *symptoms of metabolic alkalosis*, which include:

- An increased $NaHCO_3$
- Atrial tachycardia and depressed T waves associated with hypokalemia
- Attempts to retain CO_2 resulting in slow, shallow respirations
- Weakness
- Myalgia
- Arrhythmias
- Depression of ventilation—as a compensatory mechanism to retain carbon dioxide.
- Diarrhea leading to a loss of hydrochloric acid
- Fidgeting and twitching tremors associated with hypokalemia or hyperkalemia
- Nausea
- Vomiting
- Tetany
- Increased neuromuscular irritability
- Confusion
- Seizures
- Lethargy
- Coma
- Anorexia
- Paralytic ileus (due to hypokalemia)
- Dizziness
- Tremors
- Hyperreflexia
- Paraesthesia
- Muscle cramps

Management

The following are the correct nursing intervention for treating clients with metabolic alkalosis:

- Administering potassium replacements
- Assessing for neurological changes
- Monitoring for dysrhythmias
- Monitoring intake and output

Bicarbonate is still involved in metabolic alkalosis. Rarely, over-administration of bicarbonate or ingestion of bicarbonate in antacid preparation can induce metabolic alkalosis, but this is normally temporary. Abnormal elimination of hydrogen ions from the body could be the primary concern. Bicarbonate, which would normally be absorbed through the buffering of these missing hydrogen ions, accumulates in the blood. Gastric juice is acidic, and gastric aspiration or another disease phase in which the body loses its gastric material represents a depletion of hydrogen ions.

Projectile vomiting of gastric juice, for instance, explains the metabolic alkalosis that can arise in patients with pyloric stenosis. Extreme potassium depletion can induce metabolic alkalosis due to the reciprocal relationship between hydrogen and potassium ions.

Compensation—a consequence of acid-base disturbance, it is important for survival that the pH should not waver too much from normal, and the body will want to restore an unhealthy pH back to normal when the acid-base equilibrium is disrupted. Compensation is the name assigned to this life-saving process. To grasp the compensation, it is necessary to remember that pH is regulated by the ratio $[\text{HCO}_3^-]$: $p\text{CO}_2$ (a). As long as the ratio is normal, the pH would be normal. Consider a metabolic acidosis patient whose pH is lower because bicarbonate $[\text{HCO}_3^-]$ is low. To compensate for the low $[\text{HCO}_3^-]$ and recover the all-important ratio to normal, the patient should lower his $p\text{CO}_2$ (a). Chemoreceptors in the respiratory area of the brain respond to an increasing concentration of hydrogen ion (low pH), which induces increased breathing (hyperventilation) and thus increased removal of carbon dioxide; $p\text{CO}_2$(a) decreases, and the ratio $[\text{HCO}_3^-]$: $p\text{CO}_2$(a) returns to zero. Recompense for metabolic alkalosis in which $[\text{HCO}_3^-]$ is elevated, by comparison, implies respiration depression and thus carbon dioxide retention, such that $p\text{CO}_2$(a) raises to balance the increase in $[\text{HCO}_3^-]$. However, respiration depression has an unexpected side effect of threatening sufficient tissue oxygenation.

Respiratory compensation for metabolic alkalosis is, therefore, minimal.

Primary disturbances of $p\text{CO}_2$(a) (respiratory acidosis and alkalosis) are compensated by renal adjustments of hydrogen ion excretion resulting in changes in $[\text{HCO}_3^-]$ that compensate for the primary change in $p\text{CO}_2$ (a). Renal compensation for respiratory acidosis (raised $p\text{CO}_2$(a)) therefore involves increased bicarbonate reabsorption, and renal compensation for respiratory alkalosis (reduced $p\text{CO}_2$(a)) involves reduced bicarbonate reabsorption.

The following table summarizes the blood gas results that characterize all four acid-base disturbances before and after compensation.

The “acid-base balance:” compensation restores normal pH.

Primary disturbance				
	Respiratory acidosis primary increase	Respiratory alkalosis primary decrease	Metabolic acidosis primary decrease	Metabolic alkalosis primary increase In bicarb.

	in *p*CO**2**	in *p*CO**2**	In bicarb.	
Some common causes	Emphysema COPD Pneumonia Depression of respiratory center	Hyperventilation Anxiety attacks Stimulation of respiratory center in the brain	Renal failure Diabetic ketoacidosis Circulatory failure (lactic acidosis)	Bicarbonate administration Potassium depletion
Compensatory mechanism	Renal increase bicarbonate	Renal decrease bicarbonate	Respiratory decrease *p*CO**2**	Respiratory increase *p*CO**2** but limited compensation in metabolic alkalosis
Initial blood gas results (uncompen-sated)	*pH decreased* *p*CO**2** increased Bicarbonate normal	*pH increased* *p*CO**2** decreased Bicarbonate normal	*pH decreased* *p*CO**2** normal Bicarbonate decreased	pH increased p*CO2 normal* *Bicarbonate increased*
Blood gas results after partial compensation	pH decreased but closer to normal *p*CO**2** increased Bicarbonate increased	pH increased but closer to normal *p*CO**2** decreased Bicarbonate marginally decreased	pH decreased but closer to normal *p*CO**2** marginally decreased Bicarbonate decreased	Limited compensation in metabolic alkalosis
Blood gas results after full compensation	pH normal p*CO2 increased* *Bicarbonate increased*	pH normal p*CO2 decreased* *Bicarbonate decreased*	pH normal p*CO2 decreased* *Bicarbonate decreased*	Limited compensation in metabolic alkalosis

This condition is associated with an increase in serum bicarbonate levels. This is generally associated with hypochloremia and hypokalemia.

- If the alkalosis is chloride responsive, it may be corrected by intravenous infusion of isotonic sodium chloride. Potassium chloride is preferred if hypokalemia is present or edema is present.
- Vomiting/Gastric suction: Use of H2blockers or proton pump inhibitors to minimize hydrogen ion losses
- Diuretics: These can be stopped or replaced with acetazolamide or potassium-sparing diuretics.
- Chloride-resistant alkalosis must be treated based on the cause. Aldosteronism and rennin increase due to tumors must be corrected by surgery. Dexamethasone therapy may be used to suppress the HPA axis. Syndromes are corrected with potassium supplementation and ACE inhibitors, and potassium-sparing diuretics.
- Severe alkalosis (pH> 7.55) may require the administration of HCl. Patients in advanced renal failure must additionally undergo dialysis.

Respiratory Acidosis—(High *p*CO2(a), Low pH)

Respiratory acidosis is characterized by a rise in *p*CO2(a) due to poor alveolar ventilation (hypoventilation) and, subsequently, a decrease in the removal of CO2 from the blood. Respiratory disorders, such as bronchopneumonia, emphysema, asthma, and persistent obstructive airway disease, can be associated with ventilation low enough to induce respiratory acidosis.

Any medications (e.g. morphine and barbiturates) can induce respiratory acidosis by depressing the brain's respiratory center. Injury, or trauma, to the chest wall and muscles involved in breathing mechanics can reduce ventilation rate. This describes respiratory acidosis, which can exacerbate polio, Guillain-Barre syndrome, and the healing of serious injuries to the lung.

Respiratory acidosis occurs when there is alveolar hypoventilation. The lungs are unable to excrete the excess carbon dioxide, leading to an increase in PaCO2.

Respiratory acidosis may be of two types—acute and chronic. In acute acidosis, the pH is low, and PaCO2 is high.

In chronic acidosis, the renal system tries to compensate for the acidity by retaining bicarbonate. This will reflect a normal pH but causes elevated serum bicarbonate.

Causes

- **Acute respiratory acidosis:** Airway obstruction in acute phases of Asthma or COPD
- **Respiratory muscle paralysis:** Myasthenia gravis, Guillain Barré syndrome
- **Chronic respiratory acidosis:** Obstructive sleep apnoea
- Severe asthma or COPD
- Interstitial fibrosis
- Chest wall deformities

Signs and Symptoms

- Dyspnoea
- Anxiety
- Disturbed sleep, daytime sleepiness
- **As the CO2 content of the blood increases—**confusion and delirium are seen, called carbon dioxide narcosis.
- Arterial blood gases show hypoxia as well as hypercapnia and decreased pH.

Management

- As is the case with other acid-base disorders, treatment is aimed at correcting the underlying respiratory disease. Respiratory ventilation may be improved by the use of:
- **Bronchodilators—**salbutamol, ipratropium bromide, theophylline, *etc.*
- Respiratory stimulants such as medroxyprogesterone.
- **Oxygen supplementation—**to correct hypoxia.
- In life-threatening cases, endotracheal intubation and mechanical positive pressure ventilation must be used to excrete carbon dioxide from the system.

Respiratory Alkalosis: pH Up, CO2 Down, and HCO3 Down

Respiratory alkalosis is caused by low CO2 levels in the blood, which can be caused by hyperventilation.

Common causes of respiratory alkalosis include:

- Anxiety
- Being at a high altitude
- Hypoxia (or more generally, a lack of oxygen)
- **Centrally—**due to stimulation of respiratory center:
- Fear and anxiety (commonest cause)
- Stroke
- Head injury
- **Drugs and toxins—**progesterone, analeptics, *etc.*
- **Pulmonary stimulation**—asthma, pulmonary embolism, pneumonia

It is important for the nurse and nursing student sitting the NCLEX to be aware of the *symptoms of respiratory alkalosis*, which include:

- A decrease in PaCO2
- An increase in PH.
- Decreased levels of K+
- Deep, rapid respirations
- Sweating
- Fast, shallow breathing
- Palpitations, tremors

Management

- Since this condition is usually caused by anxiety, calm reassurance is an important aspect of treatment.
- Patients are asked to rebreathe into a paper bag. This causes them to inhale more carbon dioxide, thereby increasing blood levels.
- Patients who do not respond may be administered sedatives or narcotic drugs. Beta-adrenergic blockers can help reduce adrenergic effects such as palpitations.
- Fainting
- Fear
- Feelings of anxiety
- Hysteria
- Normal or decreased CO2 levels
- Numbness and a tingling sensation in the hands and feet
- Seizures
- Tetany

The following are the interventions a nurse should take when caring for a client with respiratory alkalosis. Firstly, however, the nurse should determine what the cause for the hyperventilation is before taking the correct intervention:

- Using a re-breathing bag or breathing in a paper bag to facilitate retaining CO2
- Decreasing the tidal volume and rate of ventilator settings

- Sedation
- Stress reduction

This is caused by an increase in alveolar ventilation, which

causes excess carbon dioxide to be excreted from the body. As with acidosis, this can also be acute (high pH) or chronic (normal pH), in which the kidneys have compensated by excreting bicarbonate, leading to low serum levels.

Chapter 5. Treating Imbalances

Electrolyte “Add-in's” and Ingredients

Xylitol

Xylitol is a natural sweetener that is tasty and is beneficial for oral health as it keeps minerals from being leached out of the teeth.

This makes it a wonderful consideration for beverages that have a high citrus content.

It may also be of particular interest to cyclists who are constantly sipping on their beverages through a cyclist's drinking bag.

Unsulfured Black-Strap Molasses

Black-strap molasses has a strong, distinctive flavor that you either love or don't. Although often overlooked, molasses makes an excellent sweetener and is densely packed with nutrients such as iron, magnesium, B vitamins and calcium, manganese, potassium, and zinc. Thus, making it a perfect consideration for rehydration drinks.

Citrus Juice

Citrus Juices are high in natural calcium and potassium.

That explains why they are often a staple in homemade electrolyte drinks, as well as why you see buckets of orange slices provided along marathon routes.

Choose any citrus you fancy; oranges, lemons, limes, grapefruits, they are all free game.

Baking Soda

If baking soda appears to be an odd ingredient, rest assured that it is an excellent source of the bicarbonate ion your body needs for buffering acid build-up and maintain the healthy pH balance in your bloodstream.

Water

Because dehydration is a lack of water, it should go without saying that water will be the main ingredient in your rehydration drinks.

Just keep in mind that excessive water has been known to wash away your valuable electrolytes. Very counterproductive!

Never use city tap water without filtering it first, and try to keep your water source as pure as possible.

Magnesium/Calcium

In the supplement world, these two go hand in hand.

If you are adding electrolyte potential, 1−2 calcium/magnesium tablets, crushed, or 1 Tb liquid calcium/magnesium supplement is a good guideline.

Coconut Water

Coconut water is said to be a perfect electrolyte replacement as it has the identical proportion as in human blood.

World War 2 accounts have coconut water being used when plasma supplies were low. Because of that, it has found its place in many natural electrolyte recipes. If you like the flavor, enjoy it as often as you wish. YUM!

Because coconut everything is a hot seller and the marketplace is flooded right now, be wary of just any old coconut water or harvest your own juice from a young coconut. Purchase coconut water from a higher quality supplier such as Zico.

If a label breakdown is available, a good 14-oz carton should look like this:

- 160 mg Na
- 569 mg K
- 12 g sugar

Clay

Just a quick word on clay... yes, I did say clay. In fact, therapeutic healing clays are very high in magnesium and approximately 67 other trace minerals.

One teaspoon of clay dissolved in a glass of water is very drawing of impurities, acting like a vacuum cleaner or sponge carrying poisons out of the body. Because of that, it is valuable in cases of nausea. However, it should be taken on an empty stomach and at least an hour before any other food, liquid, or medicine. Clay also falls under the category of “a little is enough.”

First-time clay drinkers are encouraged to drink only clay water and work up to drinking the clay itself. Mix the clay well in a glass of water and allow it to sit. The clay will settle at the bottom of the glass. Drink only the liquid. Clay should also be taken with plenty of water.

Taking Food High in Natural Electrolytes

Let’s take a look at nature's own provision of electrolytes! When we get into the kitchen, in the second half of this book, you will see how the sky's the limits! With a little ingenuity, you can mix, blend and brew hundreds of delicious replenishing drinks in no time at all. There will be no reason to ever opt for a boring commercial drink again!

Natural Sources of Potassium

The body needs potassium for the function of every cell in the body. These are the main functions of potassium:

- Potassium is important in heartbeat regularity
- Potassium levels help determine the blood pressure
- Potassium is important in muscle contraction, including skeletal and smooth muscles
- Potassium balance is largely controlled by the kidneys, which remove excess potassium through the urine.

A normal level of potassium in plasma (the liquid part of the blood) is about 3.5 to 5.0 mEq/L. Notice how small this number is when compared to sodium levels, which are high in the bloodstream and low in the cells. The reverse is true with potassium.

- Dried apricot
- Avocado
- Yam
- Potato
- Acorn squash
- Sweet potato
- Banana
- Soybeans
- Pinto beans
- Lima beans
- Papaya
- Spinach
- Swiss chard
- Kale
- Tomatoes
- Black-strap molasses
- Cantaloupe
- Beets
- Fennel
- Citrus fruits

Natural Sources of Sodium

We get sodium through our food as sodium in the form of sodium chloride is added to a lot of cooked and premade foods you eat. You can also get sodium in the form of sodium bicarbonate, which is commonly known as baking soda. Medications contain sodium in them, such as toothpaste, mouthwash, laxatives, and aspirin.

- Salt
- Sea vegetables
- Celery
- Celeriac

- Baking soda
- Beets
- Beet greens

Natural Sources of Calcium

Calcium plays a large role in bone formation and maintenance. Bone loss accelerates after age thirty, so that by the time a person is elderly, osteoporosis is more common. Bone loss can be prevented by supplementing the diet with calcium and vitamin D. People who have lost their parathyroid glands due to thyroid surgery suffer from low calcium and phosphorus and should take a calcium and vitamin D supplement. They should also refrain from taking in too much phosphorus. Women who suffer from premenstrual syndrome have been found to reduce their symptoms when they take 1,200 mg of calcium per day. This reduces the physical symptoms of PMS, such as bloating, mood disturbances, headaches, and food cravings.

Those who suffer from low body calcium levels seem to be at a higher risk of developing high blood pressure. This has been shown in several studies, although it is not known if calcium supplementation would turn around high blood pressure on its own. Calcium may prevent high blood pressure in people predisposed to the condition.

There have been studies linking high-dose calcium intake (up to 2000 mg per day) can reduce their cholesterol levels.

Rickets, while rare now, is a disease linked to not getting enough calcium in the diet. People at risk for stroke may benefit from taking a calcium supplement, and there is some evidence that calcium along with vitamin D is preventative against colon cancer.

- Citrus fruits
- Dark leafy greens
- Oatmeal
- Sardines
- Okra
- Almonds
- Dairy
- Quinoa
- Sesame seeds
- Broccoli
- Dried figs
- Black-strap molasses
- Seaweed
- Soy milk

Natural Sources of Magnesium

Magnesium can come from eating a healthier diet. For example, magnesium can be taken in when eating a wide variety of fruits and vegetables along with whole grains and milk products. Spinach contains high levels of magnesium, and certain breakfast cereals will be supplemented with magnesium. Meat, poultry, eggs, nuts, beans, and fish are high in magnesium and make for good magnesium levels in the body. Soybeans and legumes like peanuts, lentils, and baked beans are high in magnesium. Whole grains in the form of millet and brown rice contain adequate amounts of magnesium as well.

Ideally, we should get our magnesium through the food we eat, although some people would benefit from magnesium supplementation. Great sources of magnesium are legumes, almonds, spinach, and other greens, seeds, whole grains, and other nuts. Food high in fiber also tends to be high in magnesium. Certain bottled waters and even tap water can be good sources of magnesium intake. Of the magnesium we take into our bodies, only about 30−40% is actually absorbed by the gastrointestinal tract.

You can purchase magnesium supplements in the form of a magnesium salt made of magnesium citrate, magnesium oxide, and magnesium chloride.

When reading the label, the magnesium amount is the weight of the magnesium alone and not the weight of the magnesium salt in the supplement. Magnesium citrate, magnesium lactate, magnesium chloride, and magnesium aspartate are particular magnesium supplements that are readily bioavailable once taken in. High zinc intake can interfere with the absorption of magnesium.

Certain laxatives contain high doses of magnesium, such as Phillip’s Milk of Magnesia®. Certain heartburn medications also contain a great deal of magnesium. Rolaids® is an example of a high source of magnesium.

- Avocados
- Figs
- Dark chocolate
- Spinach
- Swiss chard
- Pumpkin seeds
- Prunes
- Apricot
- Pineapple
- Green leaf vegetables
- Broccoli
- Nuts
- Dairy
- Black-strap
- Molasses
- Kelp and sea vegetables

Natural Sources of Chloride

Chloride helps maintain proper osmolality in the body. It also combines with hydrogen iron to make hydrochloric acid, which is a major factor in the digestion in the stomach. Hydrochloric acid breaks down ingested proteins, activates intrinsic factors in the stomach, responsible for the body’s uptake of vitamin B12. It is transported via chloride channels in the stomach in exchange for bicarbonate, which is another negatively charged ion, in order to create the gradient between hydrochloric acid and sodium hydrochloride outside of the stomach.

Chloride also helps to maintain the pH balance of the bloodstream by actively and passively passing through the red blood cells in exchange for hydrochloride ions so that the body can maintain a pH balance in the bloodstream of around 7.4.

In addition, it aids in the release of CO2 in the respiratory system and helps support the electrical activity that allows for messages to travel from one nerve cell to another or from one

muscle cell to another muscle cell. You can't have an excess of ions, positive or negative, in the body, so chloride acts as the primary mineral element within the interstitial fluids, cellular fluids, and the bloodstream.

The normal reference range for chloride varies with age. For example, a normal chloride content in the adult blood is 96−106 mEq/L, while newborn infants can have a chloride content in their blood plasma of between 96 and 113 mEq/L. Adults secrete about 140−250 mEq per 24 hours sample in the urine per 24 hours if they have healthy kidney function. Children and toddlers excrete lesser amounts of chloride in the urine, in the range of 15−176 mEq/24 hours sample.

Remember that chloride concentrations go along directly with the levels of sodium and potassium levels as they are found in the dissolved form of NaCl and KCl in the body. For this reason, tests of chloride are rarely done alone but are performed in conjunction with the potassium, sodium, and bicarbonate levels of the blood in a chemistry profile. More information can be retrieved from an entire electrolyte panel than can be done by doing electrolyte levels separate from one another.

Chloride is found as a part of sodium chloride or table salt.

Whenever we consume salty foods, we are causing a relative increase in both sodium and chloride in the blood and interstitial fluids. If you take a salt substitute, such as potassium chloride, you get a matching rise in both potassium and chloride. In this form, potassium chloride or KCl is mainly found within the cells of the body.

Other sources of chloride include the following:

- Olives
- Rye flour
- Kelp
- Lettuce
- Tomatoes
- Celery

There is a lot of chloride in seawater; however, it is not recommended for consumption as the sodium chloride level in seawater is much too high to drink, and it can cause both hypernatremia and hyperchloremia. Chloride does not have to be taken as a supplement as it can be found in most foods we eat on a daily basis unless you consume a very low salt diet. In such cases, chloride would be supplemented with potassium chloride, which is the main salt substitute found on the market.

- Sea salt
- Mineral salt
- Sea vegetables
- Green leafy vegetables
- Tomatoes
- Celery

Natural Sources of Phosphorous

Much of the phosphorus in our diet comes from a wide variety of foods, such as eggs, milk, fish, legumes, grains, and cereals. Carbonated beverages of any type contain a lot of phosphorus, even though they are not always healthful in other ways. Food additives also have a great deal of phosphorus in them. It is recommended that we take about 700 mg of phosphorus daily. Amounts of phosphorus exceeding 4 grams per day are not healthy for you, so you should watch your phosphorus intake, especially if you have kidney problems. The calcium intake in your diet should roughly match the amount of phosphorus in your diet because bones and teeth require equal amounts of these minerals. It is rare to have a phosphorus deficiency because it is so plentiful in the diet.

- Pumpkin, sunflower seeds, and nuts
- Fish
- Yogurt and dairy
- Soy products
- Beans and lentils
- Garlic
- Wheat germ
- Dark chocolate
- Mushrooms
- Broccoli
- Peanut butter

Other Components

Aluminum Hydroxide (Amphoget)

- Liquid forms are more effective
- Tablets should be chewed and ingested with half a glass of water

Action

- Neutralizes gastric acids

Side effects

- Constipation
- Decreased phosphorus

Calcium Carbonate (Tums)

- Liquid forms are more effective
- Tablets should be chewed and ingested with half a glass of water

Action

- Elevates gastric pH
- Reduces pepsin activity

Side effects

- Constipation
- Hypercalcemia

Calcium Gluconate

- Check for signs of renal calcium calculi

Action

- Used in the treatment of hypocalcemia and magnesium toxicity

Side effects

- Can cause constipation
- Can lead to Hypercalcemia

Magaldrate (Riopan)

- During the treatment, the nurse should monitor the client's magnesium levels

Action

- Neutralizes gastric acid

Side effects

- Can cause diarrhea
- Increases magnesium levels

MgSO4

- Insert Foley catheter
- If administered IV, a controller should be used and titrate dosage
- Monitor intake and output every hour
- **Monitor for toxicity—**check for hypotension, oliguria, decreased respiration, and

absence of knee jerk reflex

Action

- Used in the treatment of hypomagnesemia

Side effects

- Diarrhea
- Hot flashes

Potassium Chloride

- Check client's renal function before administering
- If oral liquid potassium is administered, give it with juice for better absorption.
- If potassium is administered IV, it should be diluted, and an IV controller must be used for infusion.

Action

- Used in the treatment of hypokalemia

Side effects

- Liquid potassium is bitter
- Irritating to the vein
- Can cause cardiac arrhythmias
- Can cause muscle spasms

Sodium Bicarbonate

- During the treatment, the nurse should monitor blood pH

Action

- It acts as a systemic and local alkalizer

Side effects

- Can cause alkalosis
- Can lead to acid rebound

Chapter 6. Answers to Exercises

1. **The bulk of Phosphorus in the form of phosphate can be found in what body area?**

a. Bones
b. Bone marrow
c. Teeth
d. Serum

Answer: a. Phosphorus is found mostly in bones and teeth; however, as there are more bony areas than teeth, phosphorus is mainly found in bones, combined with calcium.

2. **A normal blood pH is between_________ and ____________.**

Answer: 7.35, 7.45

3. **A client has a blood pH of 7.3. You know that this represents what?**

a. Alkalosis
b. Normal pH value
c. Acidosis
d. Neutral pH value

Answer: c. A client with a blood pH of 7.3 is suffering from acidosis.

4. **A client is suffering from respiratory failure and has an excess of CO2. What condition is the client suffering from?**

a. Metabolic acidosis
b. Metabolic alkalosis
c. Respiratory acidosis
d. Respiratory alkalosis

Answer: c. Underbreathing causes an excess of CO2, which contributes to acidosis. Because the cause is respiratory, the client is suffering from respiratory acidosis.

5. **What would the client's respiratory response be to a low CO2 level?**

a. Increase rate of respiration.
b. Increase depth of respiration.
c. Decrease respiratory center stimulation
d. Decrease rate and depth of breaths

Answer: d. The client would decrease the rate and depth of breaths in order to hold onto more CO2.

6. **In cases of blood acidosis or alkalosis, what is the first response to alter the pH balance?**

a. A change in respiratory rate
b. A change in renal excretion of acids or bases
c. Sodium attaches to Cl or HCO3-inside the cells
d. Potassium is shunted outside the cells.

Answer: a. Renal responses to changes in pH can take hours to days, and changes in sodium binding do not appreciably affect pH in the cells. Potassium shifts do not appreciably change extracellular pH. Therefore, the first response to alkalosis or acidosis is to change respiratory function.

7. **How does the kidney respond to pH increases in the bloodstream?**

a. It holds onto NaHCO3.
b. It conserves H+ and excretes NaHCO3.
c. It excretes KOH and holds onto NaHCO3.
d. It conserves albumin and excretes H+.

Answer: b. In response to a pH decrease, the kidneys hold on to H+ and excrete NaHCO3.

8. **A client has a normal urine pH of 6. Why is this so?**

a. It excretes H+ ions more than it excretes bicarbonate.
b. It excretes albumin, which is acidic.
c. It excretes acidic by-products of cellular metabolism
d. It holds onto more CO2 than HCO3-.

Answer: c. The kidneys excrete by-products of cellular metabolism, which make the urine acidic.

9. **A client has an arterial blood gas with a pH of 7.45. What might this represent?**

a. Compensated alkalosis.
b. Respiratory acidosis.
c. Respiratory failure.
d. Acute hypoventilation.

Answer: a. A client with a blood gas showing a pH likely has a compensated alkalosis. The others represent situations of low pH.

10. **In determining whether or not a blood pH of 7.3 represents respiratory acidosis, what part of the blood gas determination should be looked at next?**

a. The HCO3-level
b. The PaCO2 level
c. The ratio of HCO3-to PaCO2
d. The urinary H+ level

Answer: b. The blood gas PaCO2 level will tell you whether or not a pH of 7.3 is respiratory acidosis or not. If it is elevated, the person likely has respiratory acidosis because CO2 brings down the blood pH.

11. The metabolic component of acid-base balance in a client is what?

a. Albumin concentration
b. PaCO2 level
c. HCO3-level
d. NaOH level

Answer: c. The metabolic component of acid-base balance is the HCO3-level. This is determined by the kidney’s response to changes in pH.

12. You are trying to determine if there is a primary metabolic pH problem in the client. What do you look for?

a. Lactic acid levels
b. That the pH and HCO3-levels go in the same direction.
c. That the pH and HCO3-levels are reciprocal.
d. That the PaCO2 level is unaffected.

Answer: b. As long as the pH and HCo3-are going in the same direction, the patient has a primary metabolic problem.

13. A normal PaCO2 level is what?

a. 10−12 mmHg
b. 15−20 mmHg
c. 20−30 mmHg
d. 35−45 mmHg

Answer: d. A normal PaCO2 level is 35-45 mmHg.

14. Signs of hypercalcemia include the following. Select all that apply.

a. Lethargy
b. Constipation
c. Confusion
d. Muscle tetany
e. Positive Chvostek’s sign
f. Positive Trousseau’s sign

Answer: a. c. Signs of hypercalcemia include lethargy, confusion, and nausea. Chvostek’s sign and Trousseau's sign are positive in hypocalcemia, as is muscle tetany.

15. **A major cause of hypercalcemia is what?**

   a. Low calcium intake
   b. Elevated albumin in serum
   c. Bone loss of calcium
   d. High phosphate levels

Answer: b. The major cause of hypercalcemia is bone loss of calcium. Low calcium intake is unlikely to cause hypercalcemia, and elevated albumin and phosphate levels are unlikely to cause hypercalcemia.

16. **A client has a shortened ST segment and shortened QT interval with a prolonged PR interval. What metabolic problem is likely?**

   a. Hypocalcemia
   b. Hypercalcemia
   c. Hyperkalemia
   d. Hypokalemia

Answer: b. Hypercalcemia can cause a shortened ST segment, shortened QT interval, and a prolonged PR interval.

17. **X-ray evidence of hypercalcemia includes the following. Select all that apply.**

   a. Urinary calculi
   b. Osteoporosis
   c. Increased bone density
   d. Pathological fractures
   e. Mottled bone
   f. Paget's disease of bone

Answer: a. b. d. X-ray evidence of elevated calcium levels includes urinary calculi, osteoporosis, and pathological fractures. The calcium is mostly in the serum, and none of it is in the bones.

18. **Nursing interventions for clients with hypercalcemia include the following. Select all that apply.**

   a. Drink more milk.
   b. Drink 3−4 lts. of fluid per day.
   c. Eat more bananas.
   d. Eat high acid-containing foods.
   e. Take a loop diuretic.
   f. Take a thiazide diuretic.

Answer: b. d. e. Clients with hypercalcemia should drink extra fluids to prevent calculi, eat acid-containing foods, and take normal saline with a loop diuretic to draw out calcium in the urine.

19. **The purpose of IV bisphosphonates in the treatment of hypercalcemia is what?**

a. To increase urinary excretion of calcium.
b. To increase urinary uptake of calcium from bones
c. To prevent calcium release from bones.
d. To decrease urinary calculi in the kidneys and ureters.

Answer: c. Bisphosphonates prevent calcium release from the bones, so calcium levels drop naturally.

20. **The first response to metabolic alkalosis is what?**

a. Hyperventilation to blow off CO2.
b. Increase in renal loss of HCO3-.
c. A decrease in renal loss of HCO3-.
d. Hypoventilation to hang onto CO2.

Answer: d. The first response in metabolic alkalosis is a decrease in ventilation that hangs onto CO2 in order to normalize the blood pH.

21. **If a client has uncompensated metabolic alkalosis, what ABG findings are noted?**

a. pH elevated
b. PCO2 elevated
c. HCO3-is decreased
d. pH is normal

Answer: a. If the patient has uncompensated metabolic alkalosis, the PCO2 is normal, the pH is elevated, and the HCO3-level is increased.

22. **A client has lost 15 percent of his body weight within 12 hours. What is the client's diagnosis?**

a. Mild hypovolemia
b. Moderate hypovolemia
c. Severe hypovolemia
d. Hypotension

Answer: c. A patient who is suffering from 10−15% of body weight loss is suffering from severe hypovolemia.

23. **A client is hypotensive, has low urine output, and has normal hemoglobin. What is a possible cause of these symptoms?**

a. Acute hemorrhage
b. Diarrhea with fluid loss
c. Vomiting with fluid loss
d. Kidney failure

Answer: a. With hypotension and poor urine output, the patient is likely suffering from hypovolemia. The normal hemoglobin supports sudden blood loss as a cause of hypovolemia.

24. One way to assess whether the patient's hypovolemia is due to renal loss or an extra-renal loss is to do what?

a. Check a serum creatinine
b. Check a urine-specific gravity
c. Check a urine creatinine level
d. Check a BUN/creatinine ratio

Answer: b. If you check a urine-specific gravity, it should be high if the dehydration is secondary to an extra-renal cause of the dehydration. If it is low, renal losses of water may be the cause.

25. A common cause of metabolic alkalosis is what?

a. Elevated potassium level
b. EKG changes
c. Losses from GI suctioning
d. Renal failure

Answer: c. If excess H+ is lost due to gastric suctioning, there will be metabolic alkalosis. Another cause of metabolic alkalosis is giving too much sodium bicarbonate in the IV.

26. A common treatment of metabolic alkalosis is what?

a. Give HCl by IV.
b. Give Diamox by IV to promote bicarbonate excretion by the kidneys
c. Hyperventilate the patient.
d. Give potassium chloride by IV.

Answer: b. Diamox can be given by IV in metabolic alkalosis in order to increase the bicarbonate excretion by the kidneys.

27. Which of the following clients is at the highest risk of hypernatremia?

a. An elderly client with diaphoresis, high fever, and pneumonia.
b. An elderly CHF client on loop diuretics.

c. A middle-aged client with vomiting and diarrhea.
d. A sixty-year-old with SIADH.

Answer: a. A client who is sweating will lose more free water than sodium and is at a higher risk of hypernatremia. The others are likely to have low or normal sodium levels.

28. Hypermagnesemia is often associated with what condition?

a. Magnesium-containing antacids
b. Renal failure with an elevated intake of magnesium
c. Diabetes insipidus
d. SIADH

Answer: b. Elevated magnesium is often associated with renal failure, along with taking in too much magnesium.

29. A major cause of hypercalcemia is what?

a. Low calcium intake
b. Elevated albumin in serum
c. Bone loss of calcium
d. High phosphate levels

Answer: b. The major cause of hypercalcemia is bone loss of calcium. Low calcium intake is unlikely to cause hypercalcemia, and elevated albumin and phosphate levels are unlikely to cause hypercalcemia.

30. A client has a shortened ST segment and shortened QT interval with a prolonged PR interval. What metabolic problem is likely?

a. Hypocalcemia
b. Hypercalcemia
c. Hyperkalemia
d. Hypokalemia

Answer: b. Hypercalcemia can cause a shortened ST segment, shortened QT interval, and a prolonged PR interval.

Conclusion

Thank you for making it to the end of this book. Much of the electrolyte balance in our bodies is determined by the kidneys, which filter electrolytes and respond to changes in electrolyte concentration of the blood by holding onto or excreting electrolytes in order to maintain proper electrolyte concentrations in the body. If you suffer from kidney failure, the electrolytes do not balance properly. There can be excesses or deficiencies of certain electrolytes. Minerals ions are used as cofactors in enzymatic reactions that are part of cellular metabolism. They can also be used as part of the enzymes themselves.

Electrolyte balance is a big part of homeostasis in the body. There is, by necessity, more potassium in the cells than in the bloodstream and more sodium in the bloodstream than in the cells. This homeostasis is managed by potassium and sodium pumps, creating the marked difference between the intracellular milieu and the extracellular milieu.

Most diets contain enough of the various electrolytes, with the exception of possible calcium.

The intake of phosphorus should ideally keep up with calcium intake as they are used in equal quantities in bones and teeth. Unfortunately, Western diets are much too high in phosphorus intake compared to calcium intake, so that calcium is leached from the bone to maintain bloodstream concentrations of calcium and phosphorus that are equal. This can lead to brittle bones.

Electrolytes create an environment where the enzymes can work properly for all the various reactions necessary for health. The cellular and extracellular quantities of the various electrolytes determine the pH of these tissue areas so that enzymatic processes can happen in the proper pH range.

The next step is to learn about how the imbalances discussed in this book affect your own specialization in the medical field. You should also come back to this book in the future to remind yourself of how fluid, electrolytes and acid-base balance are interconnected. Fluids and electrolytes are often an extremely volatile subject, which needs constant refreshing to deliver better care. You can repeat the post-chapter exercises at periodic intervals to assess your memory.

Good Luck!